Positiv Shift Quality Experience – Potentials out of the Synchronizer

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Abstract:

In general, the driver only notices shift quality when it is poor. Unlike engine performance and handling, gear shifts are rarely perceived positively; even in test reports they are only discussed when they stand out negatively. Contrary to engines, the end customer is often unaware of whether a transmission was produced by the OEM or purchased from a supplier.

The transmission, and consequently the synchronizer, can therefore not noticeable contribute to differentiation. Why is this and is there any reason why this can't change?

In marketing the Multitronic and the DSG, both AUDI and VW have attempted to raise the awareness of the buyer for the transmission; at least the DSG has managed to familiarize the technically-minded with DCTs and make them a popular option. It will be exciting to follow whether this has created a turning point in the awareness of the end customer of the transmission.

Developers and suppliers of synchronizers, however, continue to dream of being able to print the 'HOERBIGER inside' label on the transmission as a trademark.

What to do?

By supplying the synchronizer, HOERBIGER provides the central component of the transmission featuring interfaces to the output, the clutch and, by way of the gear shift, to the driver.

The layout and design of the synchronizer play an essential role in how the driver experiences the gear shift. The OEM's developer, who ultimately approves the transmission, knows what the driver is looking for. The OEM's requirements in terms of shift characteristics are quite different and are translated into specifications for shift impuls, engage impuls, and detent force characteristic.

This paper will highlight the factors that influence the shift quality in the synchronizer design and what interactions exist. Simulating the synchronizer allows for comprehensive analyses of the parameters that support a specific layout already in the design phase. In the simulator, the changes in the synchronizer come alive without hardware.

These tools can be used to also integrate the driver more closely in the creation of the shift quality and make good shift quality consciously tangible.

HOERBIGER is the specialist for synchronizers in manual transmissions, AMTs, DCTs, and transfer cases. The product range encompasses all sizes for use in passenger cars and light trucks.

In addition to extensive synchronizer system application and manufacturing know-how, HOERBIGER also has the expertise required for developing, testing and evaluating shift systems.

HOERBIGER offers comprehensive development services both during the product creation process and for solving problems during the series production phase or with new vehicle applications.

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1. Introduction

Shift quality discussions are one of the central topics during the development phase of transmissions. The specification sheets set out characteristic values related to the shift quality. Achieving and adhering to these characteristics, for example shift impuls, can be covered only partially directly through the design of the synchronizer. The interaction of the overall system is frequently described with the demand for adherence to the targets of specific ATZ (Automobiltechnische Zeitschrift) ratings. This definition, however, is of little help to the developer of synchronizers because, for one, he only contributes a sub-system and, secondly, has no way of predetermining the system behavior independent of the transmission and the vehicle. The design and configuration are consequently based in large parts on experience. Beforehand, measures for defining suitable configurations and adjustments for the specific application are virtually non-existent. The shift quality can only be subjectively evaluated in the vehicle. Measurements must then be used to identify the features in the shift process on which the subjective assessments are based. If the development is done in a pilot production vehicle, it is quite possible for changes in the shift quality to occur again with the transition to the production vehicle.

The complexity of the factors influencing the shift quality generally leads to the mutual delegation of responsibilities and there is the risk that objective discussions are impeded.

To objectify the efforts aimed at optimizing the shift quality and align them more closely with the end user of the vehicle, this paper highlights a way in which the user's subjective expectations can be determined using a simulator and, in addition, how parameters can be derived that provide the developer with clear targets.

This procedure makes it possible to optimize the development to the requests and expectations of the end user, which is an important prerequisite for the end user's positive experience.

2. The Function of the Synchronizer System in the Vehicle

In vehicles, synchronizers are used for manual transmissions, automated manual transmissions, and double-clutch transmissions. All applications share the basic functions of the speed synchronization between the transmission shaft and gear wheel as well as of the connection between the shaft and gear wheel for torque transmission. In addition, a variety of other requirements must be considered depending on the application.

In manual transmissions, the gear shift lever and linkage establish a direct connection to the driver. Consequently, the demands placed on comfort are the highest with this application. The shift forces should be as low as possible for all operating states, and especially when the transmission is cold, the gear should not only be shiftable, but the forces required for shifting should be as imperceptible as possible. The noticeable definition of the shifting comprises many aspects. The driver should be given clear feedback on the shift process and be able to clearly determine when the gear has been engaged.

In the double-clutch transmission, an actuator controls the synchronizer. The shift speed depends on the driving situation and on the available actuator force. Because the driver is not shifting the transmission, shift noises must be eliminated and the transmission must shift smoothly.

function	problem / fault	driver’s perception
disengage gear	high disengage force	clunk in drive line
	low disengage force	unintended disengagement of

		gear
select gear	select force too high	notchy gate change
	select force too low	poor definition
	soft endstop	poor definition
synchronizing	synchronizer capacity too low	high shift effort
	synchronizer capacity too high	clunk in drive line, bouncing at shift lever
	insufficient blocking safety	bouncing at shift lever, scratch noise, engagement disabled
engage gear	double bumb	bouncing at shift lever
	blocking	engagement disabled

Figure 1: Driver’s perception on shift problems in MTs

3. Interface to the Driver

In vehicles with manual transmissions, the gear shift lever creates a direct link between the driver and the shift elements. The driver is actively aware of the shift process and expects the sequences he knows and has learned. These include noise and load changes during engagement and disengagement. Whether a gear shift is good or poor depends significantly on the experiences and related expectations of the driver. Simply switching to a different vehicle may lead to unfamiliar shift processes and, along with this, the related unpleasant perception.

While vehicle manufacturers will strive to optimize the shift processes of their vehicles, they will change familiar patterns only gingerly. The related customer retention involves not only the gear shifts, but the entire layout and operation. The driver is supposed to be at ease in a vehicle "of his brand" from the very start. This also includes that the operation that was learned can be used and that the handling of the vehicle is consistent with the previous experiences.

Vehicles equipped with automated transmissions and double-clutch transmissions lack the direct interface between the synchronizer and driver. While the driver can still issue shift commands in the manual mode, this option no longer exists in the automatic mode.

This inevitably leads to a fundamental change in the perception and evaluation of the gear shifts. Ideally, the driver will detect the shifts only on the tachometer. Yet reality is slightly different.

In vehicles with automated manual transmissions (AMT), the torque flow is still interrupted when changing gears by the opening of the clutch. The driver notices this interruption and the engagement and disengagement quality. Its assessment is particularly negative if the interruption takes too long and, additionally, intense load change reactions are perceptible. The synchronizer plays only indirectly a role in this. It is one of the components that determines how long it takes for the new gear to be synchronized and engaged.

In vehicles featuring double-clutch transmissions (DCT), the interruption of the torque flow described above is completely eliminated, so that ideally the gear shifts can only be detected based on the tachometer and changes in the engine sound. The gear change per se merely involves the switching from one clutch to the other.

The synchronization process is carried out independently of this in the no-load subtransmission before the clutches are switched. The driver cannot associate the resulting noise (e.g. clicking) or bucking motions, and these create insecurity.

In all cases, the synchronization must not be noticeable and unpleasant for the driver. This realization also explains the problem that the developer is faced with. In general, the driver cannot provide any useful responses to questions as to how the flow of a gear shift should be or how it should feel. The gear shift lever is operated according to a learned pattern; it is not a conscious act. It is therefore only noticed when it varies from the known pattern.

The driver evaluates a gear shift as being precise, notchy, spongy or sluggish, for example. These terms do not directly relate to the technical conditions of a transmission; in general, they are shaped by comparisons with everyday processes. Because the shift process is influenced by all the elements of the shift system (gear shift linkage, synchronizer, drive train etc.), these elements are all considered in the shift comfort evaluation. In order to translate these terms into physical properties, the driver must be offered different gear shifts which he then evaluates.

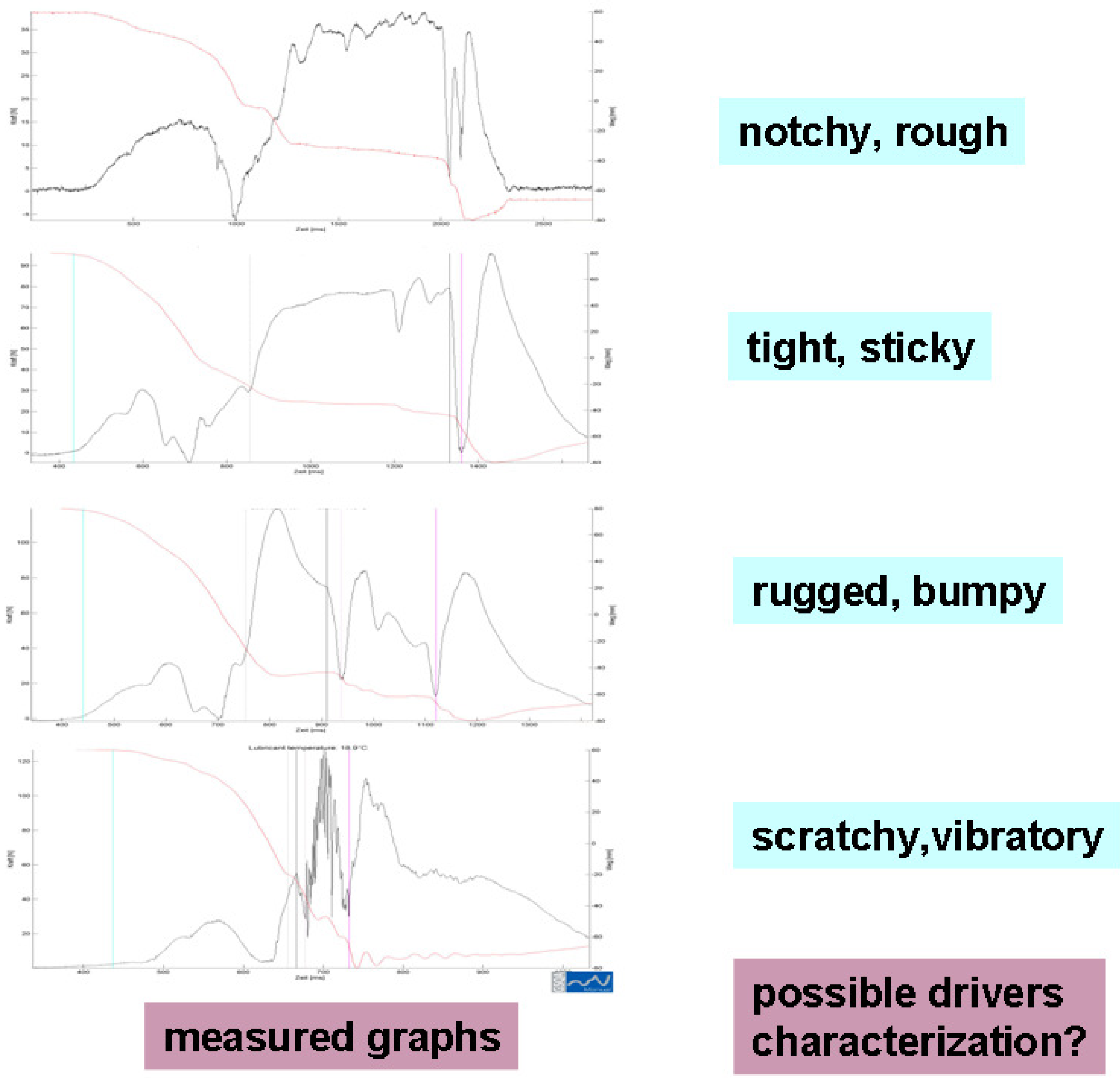

Figure 2: What is the correlation between perception and measurement?

Once a correlation has been successfully established between objective shift processes and subjective descriptions, the developer can take deliberate action to improve the shift quality and hence the perception by the driver.

4. What can simulations contribute?

Today, specification sheet requirements such as shift force integrals or the maximum allowed shift forces at the gear shift lever are the norm. They can be varied in the simulation model and subsequently verified on the simulator.

It is possible to analyze the effects of the friction system, e.g. friction coefficient curve and chamfer angle of the blocking teeth. Likewise, properties of the overall transmission system, e.g. drag torque, detent forces, mass, etc., can be varied and their impact on the specification sheet requirements can be spotlighted.

The results of the simulation can be used to derive the design of the synchronizer system. The results greatly depend on the quality of the models used for the drive train and shift system. Negative influences from the transmission and vehicle environments, such as detent elements, gear shift lever ratios, drive train dynamics, internal friction, elasticity and damping, can be compensated for by measures in the synchronizer systems only conditionally. The simulation therefore examines primarily modifications to the shift system and provides suggestions for optimization.

The dynamic simulation and analysis of shift processes and the evaluation of the shift quality are carried out after the validation on component test benches developed in-house and, following the system analysis in the transmission, by measurements on the test bench and in the vehicle.

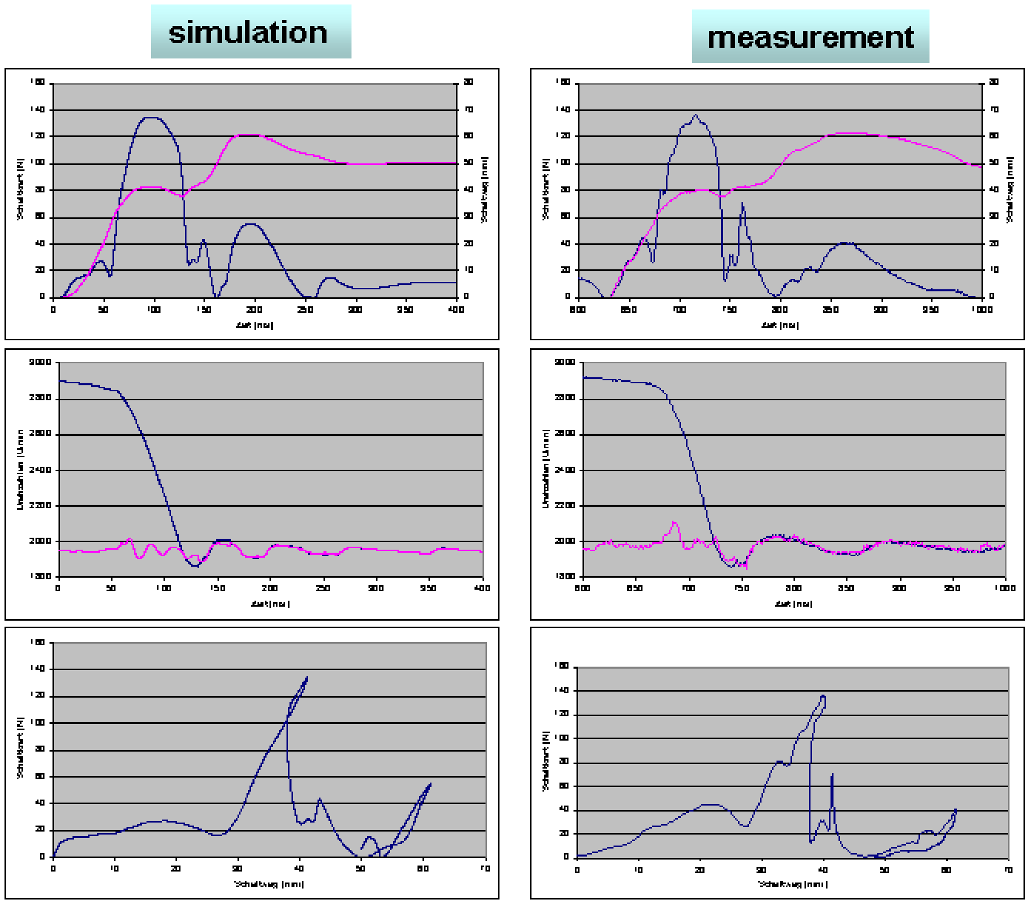

Figure 3: Simulation model validated by measurements

Simulating the synchronizer allows for comprehensive analyses of the parameters, which support a specific design early on. By deliberately varying the parameters based on statistical test methods (Design of Experiments, DoE), shift comfort analyses and optimizations can be objectively examined and evaluated as early as the design phase.

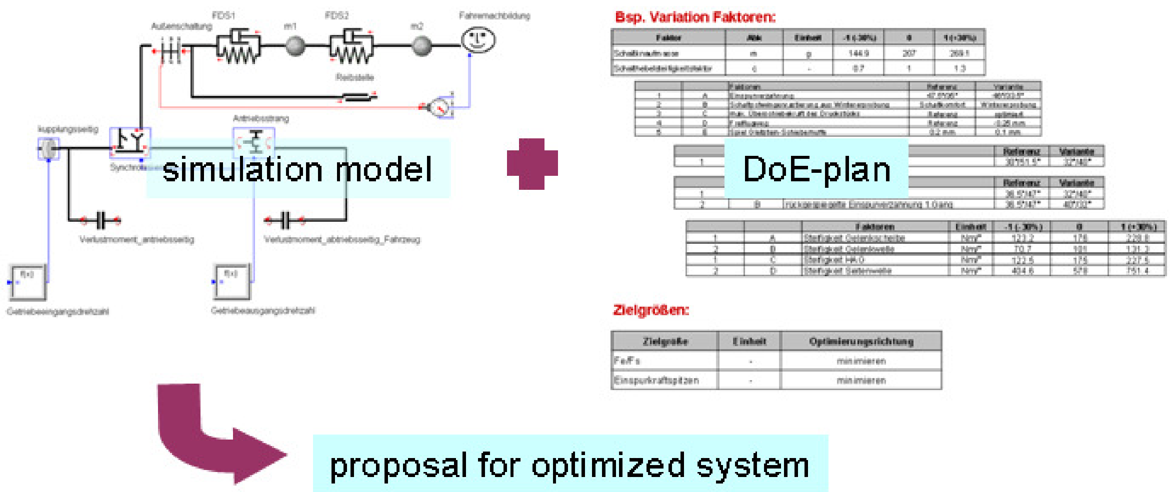

Figure 4: Application of simulation for shift system optimization

5. Shifting with the HOERBIGER Shift Simulator

Can shift quality be generalized?
The challenge and the objective of the HOERBIGER shift simulator is to subjectively evaluate different real transmission types, in consideration of complete vehicle models, under constant overall conditions.
Using the simulator, the shift comfort analyses in the transmission are carried out and evaluated without real hardware. Select parameters can be directly defined and changed via a real-time platform. Immediately after that, the haptic evaluation of the effects takes place using force feedback shift force actuators in the simulator.

The shift simulator can be operated in several modes.

Based on a behavioral model (force-travel relation), modifications to the shift gate and detent force curves as well as the influence of frictional forces and rigidity become transparent and traceable. This allows for comfort features and specification sheet requirements to be highlighted and put up for discussion.

The HOERBIGER shift simulator makes it possible e.g. to "feel" the perception of a 2nd pressure point with a rising shift force or increasing shift impuls.
It is possible to subjectively evaluate and answer questions such as where are the thresholds of load peaks for transmissions that are suitable for customers and are characteristics such as the position or time of the disturbances decisive for the evaluation.

Example: Load impulse when engaging the gear of 3 Ns

- What are 3 Ns?
- How does a impulse of this magnitude feel at low and high forces?
- Is the position or the time of the impulse decisive for the evaluation?

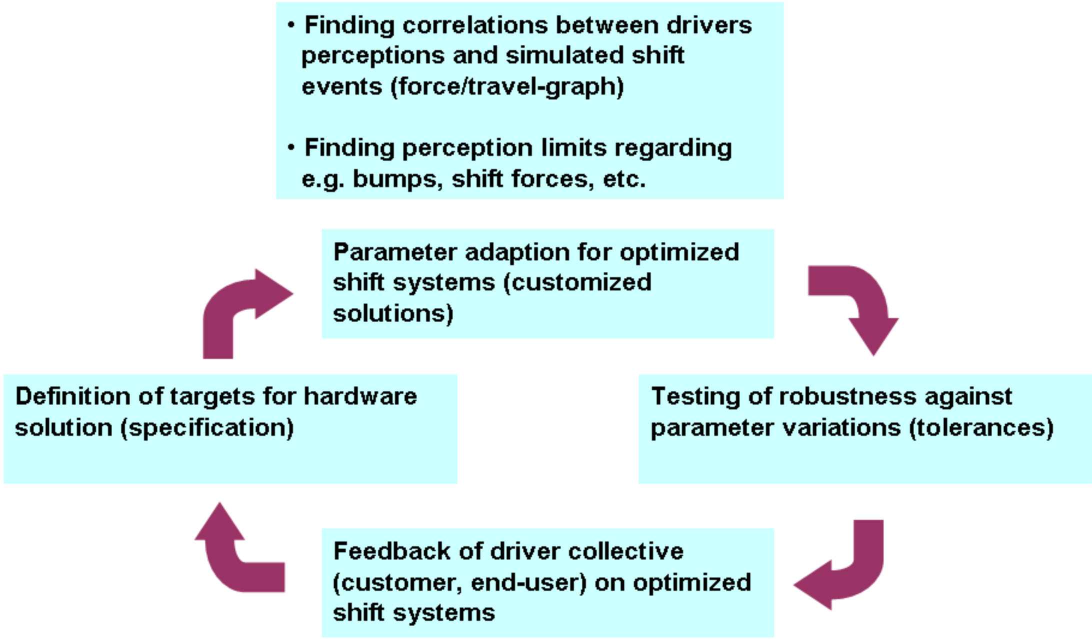

Figure 5: Development process using the shift simulator

The shift simulator can also be operated with a physical simulation model of the overall vehicle – including the drive train, the transmission with its components, shafts, wheel sets and synchronizers as well as the shift lever and linkage.

The model comparison is carried out using real vehicle measurements.

Factors like changes of geometric parameters and characteristic curves, such as friction coefficient curves, are then displayed and promote the understanding of the system. Moreover, it allows areas of responsibility of the customer-supplier relationship to be defined and improvement potential to be highlighted.

Discussions for a better understanding of the shift comfort can take place directly on the simulator, and threshold ranges can be established. This also helps to gain clarity with respect to concepts and the common technical jargon between internal and external customers as well as suppliers, e.g. grinding, grating, washboard road behavior, crashing, toughness, blocking, synchronizer humming, tight, sporty and comfortable.

The shift simulator from HOERBIGER supports the developers at an early stage of the concept phase of the product creation process in the design and evaluation of innovations. Moreover, the simulator is used for customizing, i.e. for adjusting and configuring the optimal customer design, shortening the development cycle through reduced development periods and prototype costs.

This allows the influences of the synchronizer on the transmission, and hence on the shift comfort, to be simulated and highlighted early on, lastingly improving the quality.

In the simulator, the changes in the synchronizer come alive without hardware.

6. Shift Quality Optimization Procedure

Having the different analytical, simulation and evaluation tools available allows procedures to be matched to the respective task.

Within the scope of classic development processes, and also with problems that occur during series production, the analysis using vehicle measurements ranks at the top. Experts can use the findings from the measurements to derive modifications.

If this is not sufficient, an option is to create a simulation model, reconcile it with the vehicle measurements, and solve the problem through deliberate parameter variations. The statistical DoE test method advantageously reduces the number of combinations to be analyzed and additionally identifies the significance and interactions of the parameters under review.

These procedures come into play at a time where the design has already been completed and a large portion has been invested in the production tools. By this point, the development process has been carried out, to the extent possible, based on specification sheet requirements. Demands that are placed on the shift quality, such as those defined in part in the form of ATZ ratings, can only be evaluated in the overall system, that is, in the vehicle.

The use of the shift simulator makes it possible to directly correlate the driver's assessments to the parameters of the components of the shift system. Gear shifts evaluated positively by the driver can thus be reconciled with shift force curves, and additionally it is possible to determine the design parameters required to achieve pleasant shift force progression.

Figure 6 shows how the shift simulator can be integrated in the development process. The analyses on the shift simulator can be used to establish which shift impulses and which load peaks are acceptable to the driver, and how the external shift mechanism and the detents influence the driver's evaluation. The simulator tests can be carried out with the customer's developers, and the results can be added as specification sheet items and defined for the aspired shift quality.

A key prerequisite is that the behaviors of the drive train and of the external shift mechanism correspond to those of the target vehicle. The OEM must supply the relevant information for modeling the vehicle periphery.
Following the simulator sessions, the simulation enables further analysis of the parameter effects, and in particular interactions and the robustness of the results can be verified. Only then should the system configuration and the component design be established.

In general, there will be no one ideal solution that optimally satisfies all the requirements. It is therefore useful to develop variants that emphasize different characteristics. For example, in one case the focus could be the lowest possible shift forces, and in another the emphasis could be placed on minimizing the load peaks.

The corresponding prototypes are measured and subjectively evaluated in the third phase in the vehicle. If the models are of good quality, the comparison of the recorded measurements with the results from the simulation and the simulator tests should confirm the intended optimization direction. If the concordance is insufficient, the models must be calibrated based on the measurement, and a second development cycle must follow.

While comprehensive experience is available for modeling the synchronizer component, the implementation of the drive train may be more problematic. Here it is recommended to carry out prior measurements and not to rely solely on the OEM's information.

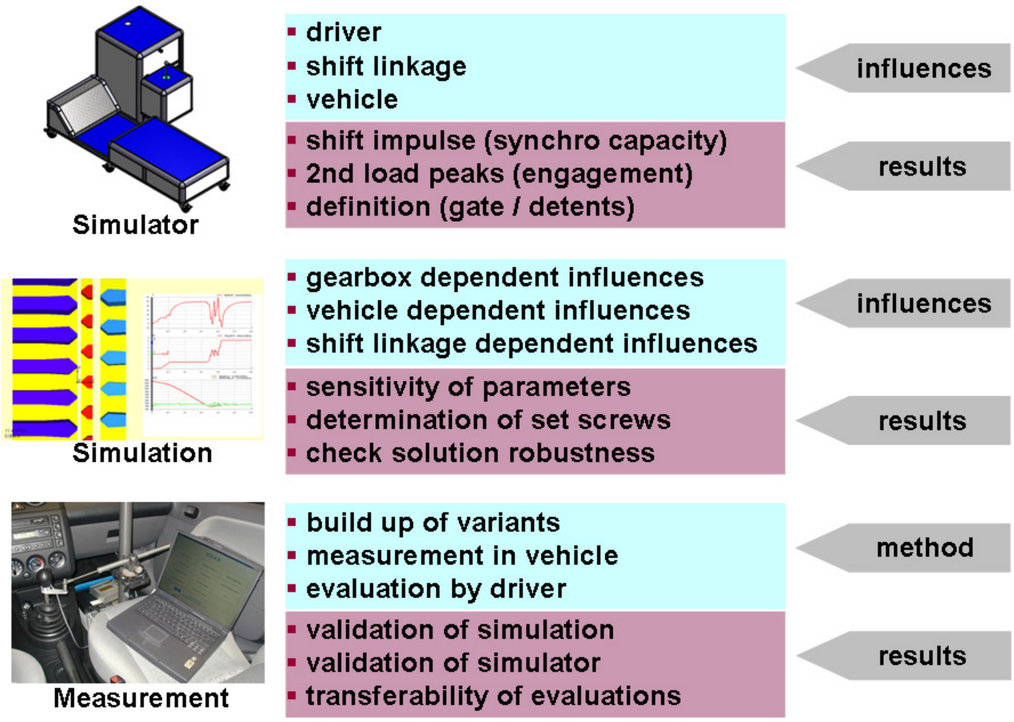

Figure 6: Combined development process

The procedure set out above takes place in the known development environment and only includes the shift quality evaluation of the customer's developer. The end user is ignored here.

The simulator also allows the end user to evaluate development objectives. The end user can provide feedback in the simulator about what is important to him and whether the assumptions must be adjusted.
This is a first step toward identification with the synchronizer.

6. Summary

The dream of the developer and supplier of synchronizer systems that the end customer will positively experience the synchronizer in the vehicle and elevate it to a quality feature is not likely to come true any time soon. The majority of drivers will only distinguish between manual transmissions and automatic transmissions and rarely delve into the details of the technology.

Nonetheless, it should be possible to develop gear shifts more purposefully and to positively market this customer-oriented design of shift processes.

With its unique combination of measuring technology and simulation, HOERBIGER has what it takes to analyze and design gear shift systems, independently of the hardware.

By using the HOERBIGER shift simulator, the end customer can provide direct feedback on the modifications of parameters, helping to complete the development process. The developer will receive signal characteristics that can be clearly attributed to descriptive terms such as notching, bouncing or slipping and can better assess measurements and simulation results with respect to customer perception.

Thinking further, it is also possible to check development goals and specification sheet requirements for their relevance to the end customer. Perception limits can be determined, and shift and detent forces that are perceived to be unpleasant can be ascertained.

Finally, the parameters that result in improved shift quality can be identified independently of outside influences. As a result, validation of the planned course of action for the vehicle and production of prototypes can be carried out systematically.

[1] Schreiber,U.; Todtermuschke, K.;Back, O.: Definition and Experience at the Simulator with Real-Time Models for Synchronizer and Powertrain, Internationaler VDI Kongress Getriebe in Fahrzeugen 2010, Friedrichshafen