01 | Noise elimination and SAREX

Target Application

Noise like squeaking, squealing or rattle, is often perceived as annoying; even if not loud, it is getting on people's nerves. A major reason for this is that noise of this type is extremely impulsive and occurs erratically. Physiological and psychological effects reinforce the impulsivity of signal in humans so that levels as much as 20dB can be perceived. The fact that such noise is neither periodic nor continuous makes it incalculable and therefore extremely annoying to humans. This is the reason why even noise of very low level canbe perceived as extremely annoying.

RATTLE IS THE CONSEQUENCE

of a hard object contacting another hard object. Thus, it is an orthogonal movement which if the gap is insufficiently large or the facility is not pretensioned can cause superficial deformation due to impact which causes noise emission either at the contact point or via resonant vibration of the involved components.

Squeak occurs only during tangential movement, when the materials coming in contact with each other produce stick-slip effects. To assess material incompatibilities, stick-slip machines were developed which simulate load scenarios of the type experienced during road drives. The stick-slip risk of pairs of material can be measured with such machines.

The combination of this information with CAD data permits the designer to identify and eliminate many potential squeak and rattle risks already at the design stage. The target of noise prevention is to develop a virually noise-free design.

Despite all efforts, however, noise will still be present in the initial and also in later versions of hardware even after a complete prevention process. The point now is to eliminate the noise before the first serially made cars are delivered to customers.

In the next step, after hardware ist available, hardware confirmation has to be done

SAREX IS A NEW FAMILY

of noise exciting systems on which components, systems and complete cars can be tested for noise.

SAREX is short for Squeak And Rattle Exciter and comprises the following engineering, hardware and software components:

1 | Engineering

Identification of the relevant excitation form
As a rule, this comprises 5 types of excitation, each of which must be translated in hardware:

Excitation due to torsion of the car or its systems, e.g., due to bumps, kerbs, etc., most of which are in the low-frequency range (SAREX-TOR)

Excitation by driving on roads (mostly in the frequency range above 5Hz) (SAREX-UNO,DUE,TRE,QUATRO,CINQUE, HUM,TOR,FB)

Excitation by humans (SAREX-HUM)

Excitation by the actuation of functions (SAREX-FUN)

Excitation by audio (SAREX-AUD)

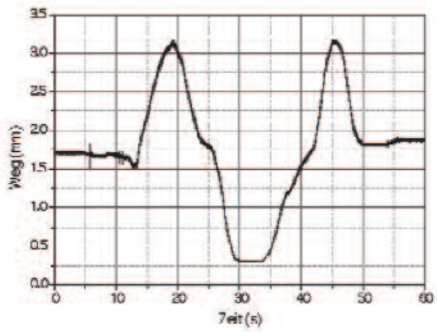
The relevant excitation types must be defined for each system under test. For example, if a door panel is tested, torsion, driving on roads, humans and audio are relevant, for an instrument panel, the types are torsion, driving on road, and for a cup holder, it is driving on road and function.

Ziegler-Instruments Engineering Quality

Once the relevant excitation types are fixed, the real load scenarios are defined in the next step:

2. Engineering as basis of system configuration: Identification of excitation profiles and limits

Anyone wanting to make excitation systems reflecting reality should measure the excitation profiles and limits beforehand. At first, the customer should make the cars or systems and the test courses available.
If a system is tested at a stage at which the car is not yet drivable, measurements on earlier models are permitted because there is nothing better to use.

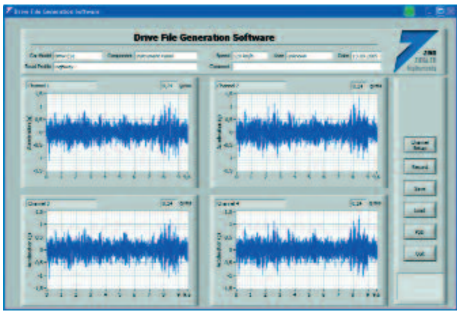


accelerator transducer

Accelerator transducers

cannot be used for recording torsion because the frequency of the movement is much too low. Distance sensors, in this case, can sense the movement but they are difficult to place. Measurements have shown that sinusoidal waves may be followed by relative movements of the order of 3.5 mm for 10 seconds. These results were obtained with a complex setup with inductive position sensors.

The excitation by driving on roads is recorded by acceleration transducers. Optimal setups use triax transducers at all fixed points of the system. This means, e.g., for an instrument panel, that measurements are made on the A column left and right, where the panel is fixed. If the part is also fixed at the floor, these points should also be included. Special software (DGS – Drivefile Generation Software) was developed for the measurements, which converts the acceleration signals measured directly, e.g., in PSDs hat can be read by shaker controllers or are available to the shaker controllers as time signal data for the time domain history. Besides, relative velocities and relative movements can also be determined by double integration. This is useful for many other evaluations as part of noise elimination.
The impact of these measurements can be seen from the following data obtained on cobbled road at a driving speed of 50 kmh.



drive file

Location	X		Y		Z	
	gmax	gnms	gmax	gnms	gmax	gnms
A-Column Co Driver	0,39	0,09	0,4	0,055	0,68	0,1,94
Seat Rail front left co	0,31	0,081	0,61	0,137	0,5	0,12

The grms in z-direction are double those in x- or y-direction at the fixing points of the instrument panel. Hence, the shaker design needed for x- and y-directions is half that needed in the z-direction. This saves nearly €20,000 in x-direction and another about €20,000 in Y-direction.
For seats, the grms in Y-direction is almost the same as that for Z-direction and the x-direction is nearly half that amount. This means that money can be saved in x-direction. It is important, however, that the Y-direction is at least as important as the z-direction and therefore seat shaking should at least be in y- and z-directions and also in x-direction, if possible.

The following measurements illustrate the comparison of excitation levels left and right.

Location	Road Profile	Speed mph	Z	
			gmx	g rms
A-Column Co Driver	cobbled road	30	0,68	0,194
A-Column Driver	cobbled road	30	0,68	0,194
Seat Rail front left Co Driver	cobbled road	30	0,50	0,12
Seat Rail front left Co Drive	cobbled road	30	0,44	0,114

Differences amount to between 5-10%, which may be enough to cause torsion or twist in the system. The following measurement is a comparison at the seat rails front and rear with distinct differences obtaining.

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It can be seen from the seat rail data that the differences between the right and left front sides are small whereas they are very large between front and rear. It follows that a 2-axis controller must be used to control front and rear separately. It will be understood from the above that any shaker system design requires measurements of drive files at all fixing points. Only a professional engineering analysis can ensure that the system performs exactly as required – neither less nor more. This can save a lot of money.

3. Knowledge of movement data

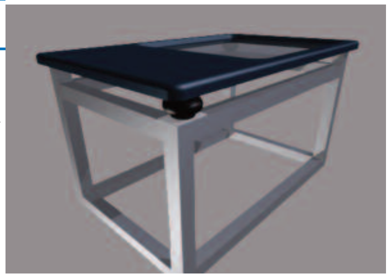
is, at first glance, of minor importance in the context of human excitation. Primarily, the force exerted to create pressure is important for generating relative movement. This can be obtained with force measuring devices. However, the force-time curve during indentation is quite important in the simulation of life-cycle tests.

Function-related noise is due to movements, e.g, of power steering columns, seats, pop-up roofs, power windows, ashtrays, cup holders, which are essentially system-related.

As far as loudspeaker-related noise is concerned, most OEMs provide audio CDs.

4. Systems

I. SAREX-TOR

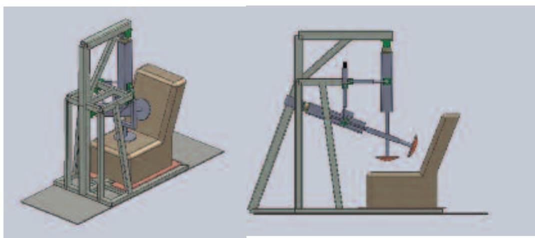


A testing system simulating torsion is SAREX-TOR.
Here, torsion is produced by motion systems at 2 corners whereas the other corners are fixed, disposed diagonally to each other. The maximum stroke is limited between 0 and approx. 5 mm by a mechanical stop. Noise can be produced by periodic excitation and the appropriate contact points can be identified by systematic examination. Objective tests of the noise level by OCIAN can be performed as a quality assuring measure.

II. SAREX-HUM

Test specifications often provide for forces that should occur at certain points, e.g., the door trim. In this case, forces of a magnitude between 250-350 N act at the door handle in y-, at the arm rest in y- and z-, at the pattern in y- and on the kerb in y- and z-directions. If a suitable measuring device is applied at these points and pressed and the contact forces are set, noise can be excited and analysed. This is done by using SAREX-HUM-MAN

SAREX-HUM-Seat was developed for seats. Two linear motors in this system apply pressure into the seat with the force as controlling variable. The stroke power and the frequency at which the power is applied were specified by the customer.



III. SAREX-UNO-SMALL

SAREX-UNO is short for Squeak&Rattle Excitation with one controlled axis. The simplest version of SAREX-UNO is the M-series from IMV available in force versions M030, M060 and M120 with uncooled force ratings of up to 740 N random

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Noise produced by many different components such as radios, ashtrays, CD player, cup holder, fresh air grilles, etc., can be tested with this series; the maximum weight of the test specimens depends on the road profile data and the grms obtained. The maximum mass that can be moved can be calculated in connection with the force data in non-cooled mode. Deducted from this are the mass of the instrument and the mass of a possible assembly table and the maximum mass of the test specimen obtained.

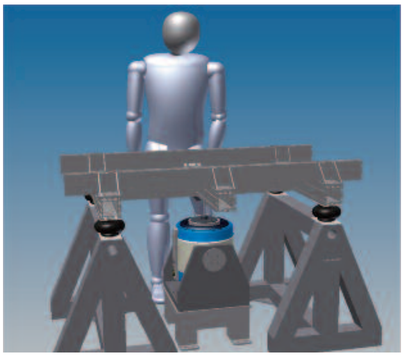
SAREX UNO SMALL

vertically auxiliary table

To improve clamping, vertical auxiliary tables are available. As shaking in x- and y-directions is often necessary, horizontal sliding tables are available. The maximum permitted mass of the test specimen is now determined by the grms values in x-and y-directions, less all moving masses, without the mass of the test specimen. The movement is controlled in all 3 spatial directions, one after the other, by the closed-loop controller.

SAREX-UNO-LARGE

or systems such as, e.g., instrument panels, center consoles, seats, door panels or doors, etc., is the typical single-axis excitation in z-directionon floating airbags.



Horizontal Table

The system comprises 2 base beams with airbags, which support the weight of the test specimen. The test specimen is adapted to the top frame. The shaker – itself a low-noise device – is linked to the frame by a stinger and transfers the road profile onto the construction. At least 2 control sensors at the suspension points of the system (e.g., A-colum position with instrument panels or seat rails positions with seats) are calculated by the controller and converted to a control signal for excitation. In this way, a closed-loop control is obtained, i.e., the road profile as set point is constantly referenced to the mean of the actual acceleration profile at the fixing points instead of with subsequent control adjustments after deviations.

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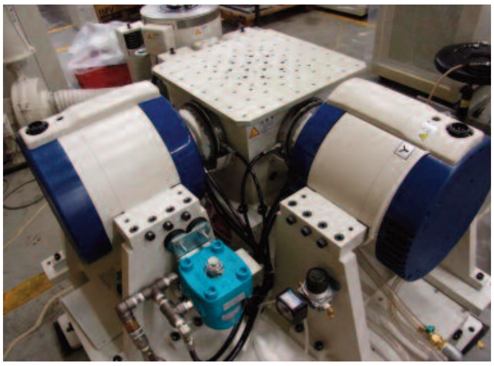
It is important to state that the controller only controls the movement in z-direction. The movements in x- and y-directions are not controlled but happen by pure chance. A fully controlled movement only in z-direction is possible without problem by additional PSG guides.

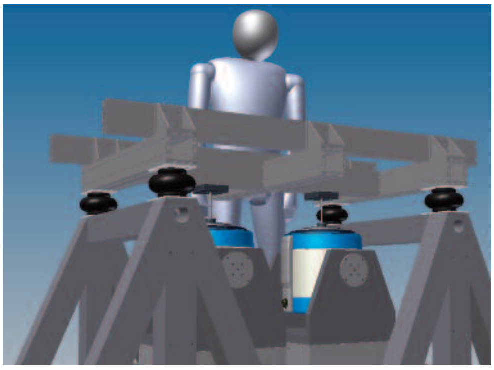
The size of the top frame depends on the size and variety of the tested object. For example, if only front seats are shaken, a small platform on which the seat is attached would be better than the version illustrated here.

If always the same test specimen is shaken, the set-up is less complex than if different instrument panels and then center consoles and then doors are tested. So, finally, each system is tailored to the customer's needs. If the accelerations measured are very high or the test specimen is very heavy (e.g., when door panels in doors and body cutouts are tested), a second shaper can be connected. This not only provides more force, the shakers can also induce a rolling movement in the system by phase inversion.

It is quite easy to extend this system to one with 6 degrees of freedom in that the shaker is inclined and the stinger docks outside the centerpoint. The distance from the centerpoint can be set by the ratios of the grms values in the different axes. It is important to remember that grms values are mean values and the actual movement, e.g., the x-direction, does not couple with the z-direction. Both forms of movement are independent of each other. Hence, the system does not reflect reality but ir is good value for money.
Such a system excites the test specimen in all directions and generates translational movements in x-y-z-directions and rotational movements around the x-y-z-axses (roll, pitch, yaw). These are not controlled, however, and the movement is purely accidental (except the z-axis).

IV. SAREX-DUE

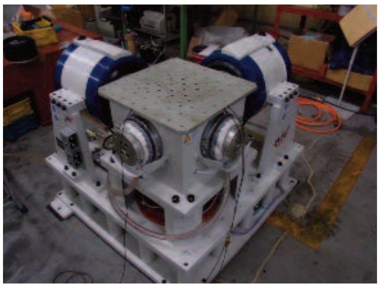




Sarex-Due has 2 controlled axes.
The DC-120-2.5L, which can excite 2 axses at the same time, can be used for small components. The size of the clamping table is 200x200 mm and the weight of the test specimen is limited to 10 kg. With this system, two axses are moved in a controlled way, i.e., the movement on the road is also imaged in both axes.
For testing larger components the shakers can be positioned as shown below:
z-z: supports controlled movement in z-direction right and left and as such reproduces vertical movement, shear movement in z-direction and roll movement around the x-axis. In that case the drive files must have been scanned simultaneously at the right and left A columns. With PSG, the movement in z direction is strictly controlled; without PSG, the system can float without control in x-and y-directions.

V. SAREX-TRE

Sarex-TRE has 3 controlled axes
Smaller components can be tested on the DC-120-2.5L, by which 3 axes can be exceited simultaneously. The size of the clamping table is 200x200 mm and the weight of the test specimen should not exceed 10 kg. This system controls the excitations of 3 axes, i.e., the movement on the road can be displayed on all 3 axes.



For larger systems, extensions with 3 excitations in z-direction or one excitation each in x-,y- and z-directions are possible. The details of the set-up depend on the results of the drive file measurement. For example, the 3 excitations in z-direction make sense in case of a cockpit if 1 shaker is placed under the simulated A-column left, one at the right and 1 shaker is fixed at the centre console fixing point. With this set-up, the z-directions, pitch, roll, yaw and all forms of torsion can be tested using a MiMo controller.

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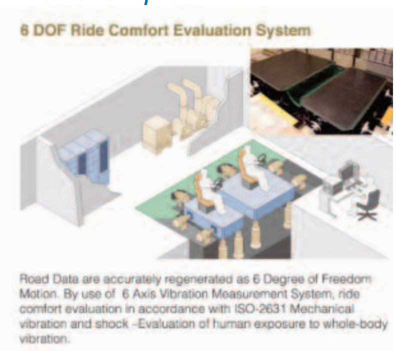
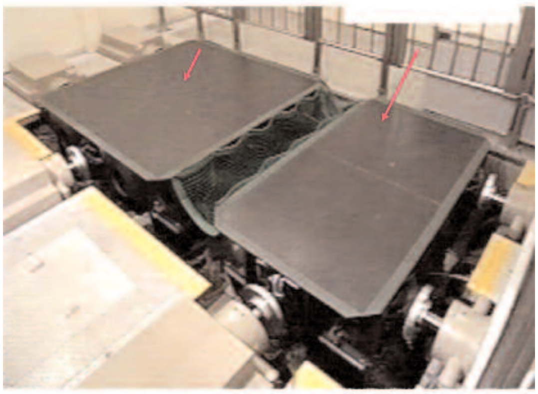
If seats are tested, excitation in all three spatial direction is meaningful and also prescribed in the test specifications of some OEMs.
The results presented at the beginning of this chapter also demonstrate that an additional or alternative control from front or rear is important.

VI. SAREX-QUATRO & CINQUE

Very many shakers can be coupled and controlled by MIMO controller for performing very different tests. Of importance, in each case, are the input measurements of acceleration to engineer the correct choice of shakers, directions of excitation and control strategies.
For example:



The driving comfort of seats is simulated by 6 DOF systems on 2 platforms:



Mounted on this systems are seats on which test 2 person sit and report on the driving comfort

VII. SAREX-FB

Where a complete car is to be tested, a method has been established by OEMs in Japan, in which all wheels of the car are excited in all three spatial directions.
The central module of the system is the ICCU which with 3 shakers docked generates controlled movements on the wheels in 3 spatial directions.

Because the control sensors can be placed at any point of the car, all movements measured on the road can be simulated by means of closed-loop Mimo controllers. Movements up to 250mm in the wheels are possible.

Summary

It is easy to provide expensive, large and complex shaker systems.
The approach by IMV and ZINS is different and comprises a large engineering input at the beginning which can save enormous cost later.
The engineering portion looks at the real load scenarios of the customer's part in the car (or in earlier models) during road drive. The measurement is completed quickly and is not expensive. The analysis of data shows the way to a system configuration that combines the required excitation directions with the optimum shaker sizes and by that can turn out to be a substantial cost saver. The system is of modular design and so many different test system versions can be implemented. In the final analysis, the system should be something of a coat for our customers: fitting, warm and protected.