

FORCE BASED SQUEAK & RATTLE ASSESSMENT

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KEYWORDS –

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ABSTRACT –

Squeak & Rattle is a nonlinear phenomenon. Most of the Squeak & Rattle simulation approaches are using a linear analysis in order to identify the limit, when this type of nonlinearity starts to occur. In previous papers [7,8,9] the relative displacement from a modal transient analysis in the critical interfaces has been used as assessment criteria for both squeak and rattle occurrence.

In this paper it is shown, how the force in the critical interface can be used as additional assessment parameter for both phenomena, squeak and rattle. For the rattle assessment it is important to perform a pretension simulation. Different pretension approaches are presented in the paper. For the squeak assessment the static friction force from test (stick-slip or rheometer) is needed.

By evaluating both the relative displacement and the force, the usage of the modal transient analysis for S&R simulation becomes even more complete and consistent. The new approach is implemented in both the pre and post processing Ansa/Meta S&R toolbar (Beta), which resulted in an improved user interface.

The different aspects of this new approach are shown in detail on a cockpit and a tailgate assembly.

TECHNICAL PAPER -

1. INTRODUCTION

Within the automotive industry Squeak & Rattle becomes more and more a standard load case during the virtual development phase. The current Squeak & Rattle simulation is based on a linear approach in time domain, which enables an efficient support during the design process [7,8,9]. The simulation approach is so far based on evaluating the relative displacement in order to assess the Squeak & Rattle performance. This paper presents a new approach by using the force output in the critical interfaces. By defining the local stiffness values along the evaluation line (E-Line) accordingly, the force output can be used for both squeak and rattle assessment.

In order to assess the force output, the pretension force and the static friction are needed as assessment criteria. The pretension force requires an additional simulation depending on the chosen pretension concept. The static friction is based on test with a stick-slip test machine or a rheometer.

By using both the relative displacement and the force from a linear simulation, the approach can identify the limit to the nonlinearity of the Squeak & Rattle occurrence. This linear simulation approach cannot describe the S&R issue itself. It rather predicts the risk for S&R. This is the most important input to the design during the virtual development phase in order to avoid S&R.

2. SQUEAK & RATTLE PHENOMENA

Squeak & Rattle is a complex phenomenon, which includes a wide range of different disturbing noises. These noises are unwanted, but not always avoidable. In a bus S&R is acceptable, but not in a car.

In order to describe this phenomenon with CAE simulation, it is important to understand the physics behind. There are two major causes.

The first one is called “rattle” and occurs, when two parts which have an initial gap in between are hitting each other normal to the contact plane.

Rattle can also occur, when two parts are in contact from the beginning due to a pretension force. The excitation of the structure causes a contact force (normal to contact plane) in between the two parts. If this inner force (operating force) is higher than the pretension force, the gap will open up.

In case of rattle there is an additional scenario called “just in touch” to take into consideration. The parts are in contact, but there is no pretension force in between. In that scenario the system is most sensitive. A very low excitation level can already cause a clear rattle noise.

The second cause is called “squeak” and occurs, when two parts are in contact and move relatively to each other in the contact plane [8,9]. The relative movement consists of a stick phase (static friction), where the parts are locally deformed in the contact area (shear deformation) and a slip phase, where both parts are sliding on each other.

Both phenomena, the rattle and squeak are nonlinear. Due to efficiency a linear simulation approach is chosen. The nonlinear phenomenon is split into two linear simulations, one evaluating the relative displacement and one evaluating the inner force.

Overview - How to assess S&R with linear simulation results			
	Simulation output	Assessment parameter (Test/Simulation)	Assessment criteria for <i>no</i> S&R
Rattle			
Defined gap	Max gap closing	Min gap size from GD&T	Min gap size > Max gap closing
”Just in touch”	Max gap closing	Min amplitude <i>from rattle test</i>	Min amplitude > Max gap closing
Pretension	Max gap force	Min pretension force	Min pretension force > Max gap force
Squeak			
No friction	Max P2P disp	Min inverse impulse rate	Min inverse impulse rate > Max P2P disp
Static friction	Max shear force	Min static friction force	Min static friction force > Max shear force

Figure 1 – S&R simulation output and assessment parameter

In Figure 1 an overview is given over all parameters which are used to describe these two major causes.

In case of rattle only the relative displacement is calculated without considering the contact. The relative displacement is compared with the minimum gap size from tolerance analysis for assessing the rattle risk. When the parts are in contact from the beginning, the inner (operating) force is calculated. If the operating force is above the pretension force, the gap will open up and there is a risk for rattle.

In order to assess the “just in touch” condition, a new rattle test has to be developed. The intention of this new test is, that it identifies the minimum relative displacement causing rattle at “just in touch” condition.

In case of squeak the relative displacement in the contact plane is calculated without considering the static friction. The maximum principal peak to peak is compared to the impulse rate of the stick-slip test to assess the squeak risk. This is the first linear simulation. The second assumes only static friction (no sliding) and the maximum shear force is calculated. If this maximum shear force is below the minimum static friction force from the test, there is no risk for squeak. The friction test procedure (stick-slip or rheometer) needs to be enhanced in order to enable the identification of the minimum static friction force for a specific material combination.

3. FORCE OUTPUT AS ASSESSMENT CRITERIA

When using the force output for rattle assessment, the minimum pretension is needed in order to consider the worst case. Depending on the chosen pretension concept, different types of simulation can be performed. A local clamping condition can be calculated with a linear static solution with 2 aligned forces. A very common pretension concept for interior parts is to deform the complete interior part when mounting the clips. This pretension can be defined as load by using CGAP elements with an initial penetration value [12]. In case of a rubber stop with a complex shape a contact analysis can be needed in order to calculate the nonlinear stiffness.

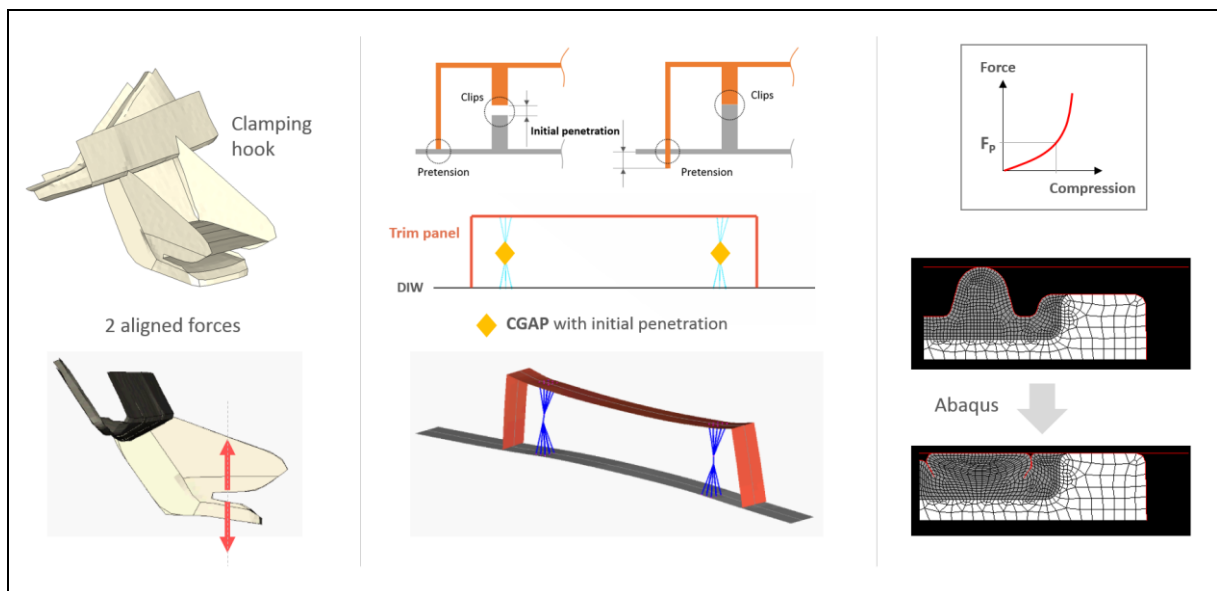


Figure 2 – Pretension force simulation

When using the force output for squeak assessment, the minimum static friction force is needed to get a worst case scenario.

Along with the impulse rate the friction force is an output of the stick-slip test. Since the stick-slip test is part of a standard (VDA norm 230-206), the spring stiffness is set to a certain value. When looking at different interfaces in a typical interior assembly, then it becomes obvious, that the interface stiffness can vary a lot, see the two lower sketches in Figure 3.

The interface stiffness has an impact on the impulse rate due to a higher deflection and has to be taken in consideration, when using the displacement based assessment. Since the friction force is independent of the spring stiffness, the force based method is an improvement in this aspect compared to the displacement based squeak assessment.

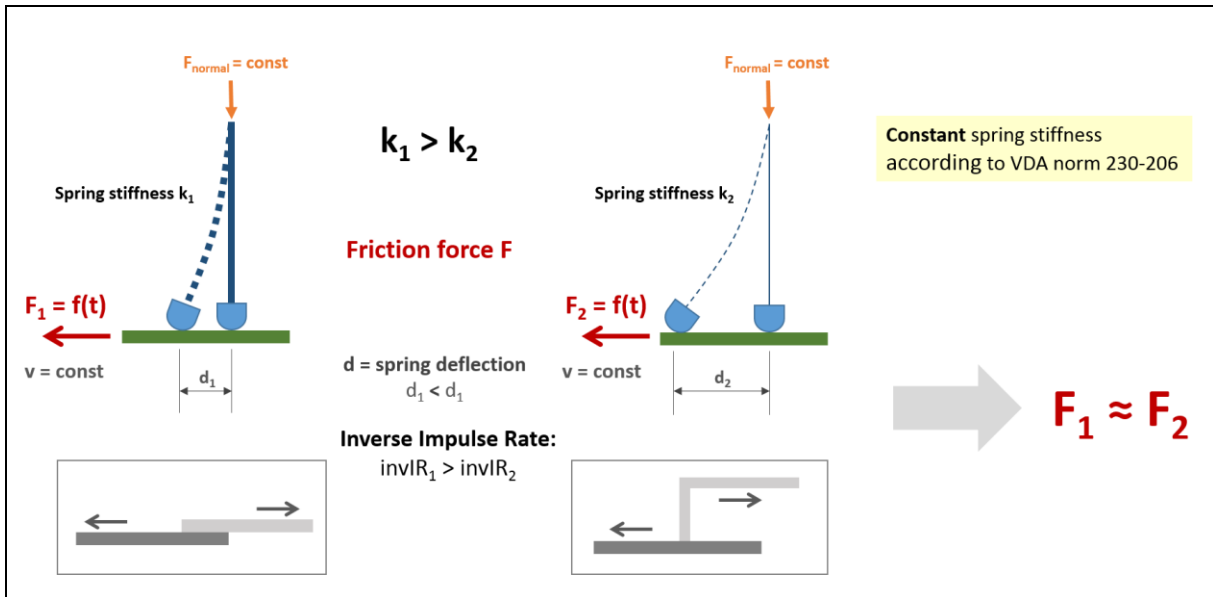


Figure 3 – Static friction force vs impulse rate from stick-slip test

In Figure 4 an additional difference between the both methods is shown. The force method requires the shear force calculation, for the displacement method the principal P2P is needed.

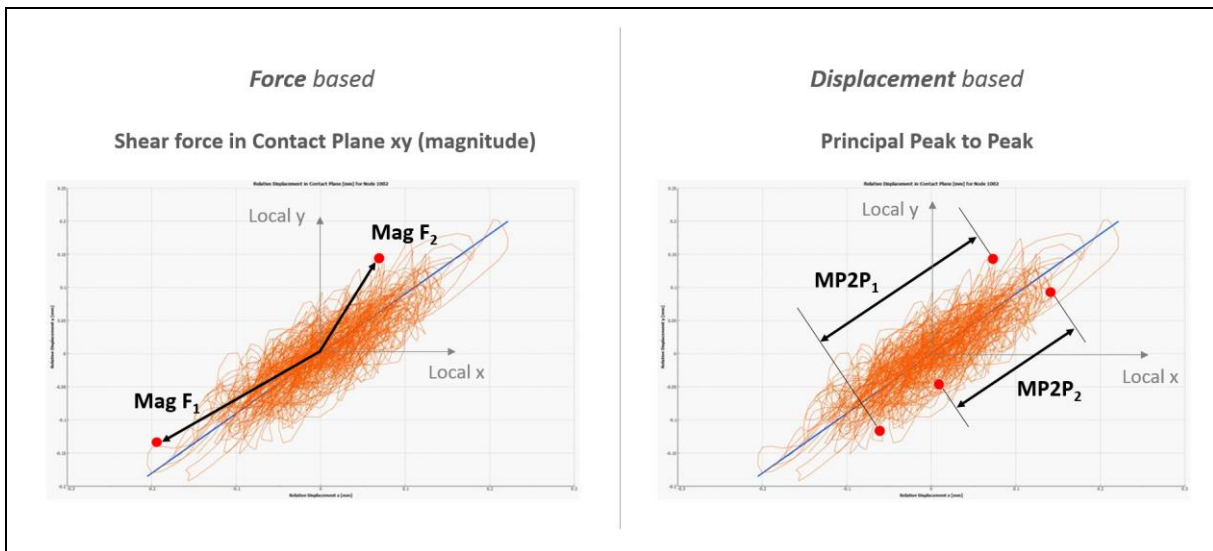


Figure 4 – Squeak evaluation - force vs displacement

4. IMPLEMENTATION IN PRE AND POSTPROCESSING

Prior to the S&R simulation a Contact Point Analysis (CPA) is performed. The CPA is a systematic way to look at the CAD geometry, the tolerance data and at the product itself in order to find critical interfaces regarding S&R. The critical interface can be either a contact or a gap. If it is not possible to assess the interface with engineering judgement, S&R simulation is needed. In the E-Line creation toolbar [11] the user can choose either a gap or a contact,

which creates a natural link between the CPA and the S&R simulation. The gap can be evaluated for rattle based on displacement. For the contact there are three options available, *Rattle Force based*, *Squeak Force based* and *Squeak Displacement based*, see Figure 5. According to these options the spring stiffness in the local directions along the E-line are created [7,8,9]. Depending on the overall stiffness close to the E-line and the spacing between the springs, the spring stiffness values have to be chosen (at least 1000 N/mm).

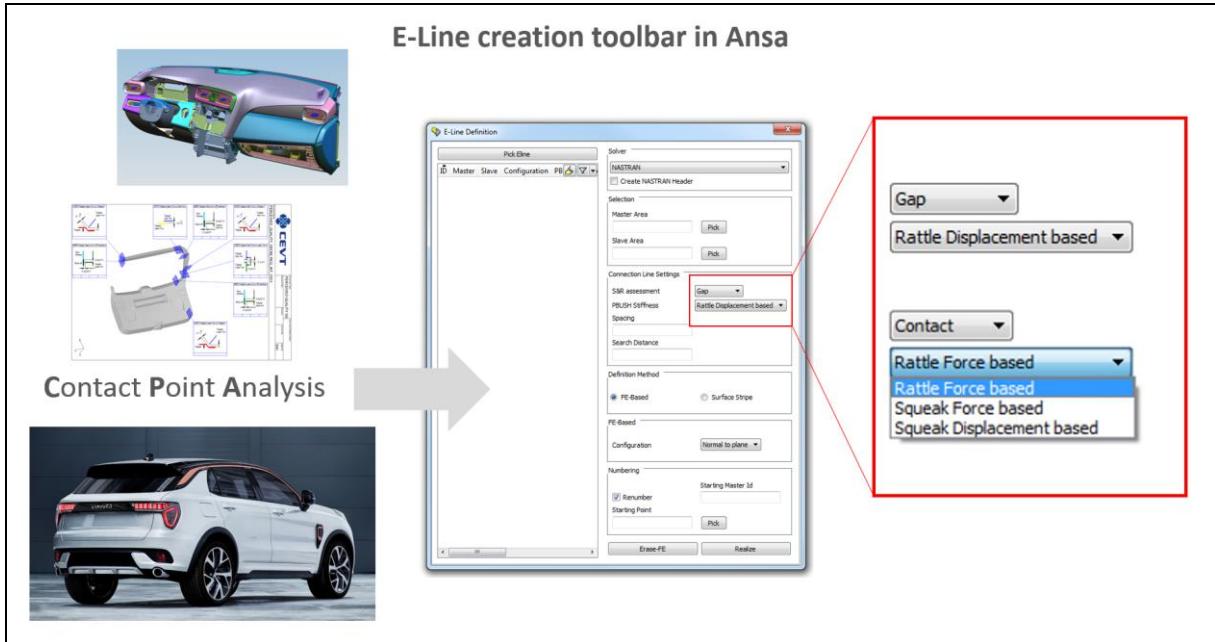


Figure 5 – E-Line creation toolbar in Ansa

Both the displacement and the force are output to a punch-file, which will be imported into Meta. Meta identifies the E-lines [11], which are displacement based and force based and makes it visible for the user. When selecting an E-line, the squeak or rattle results can be chosen accordingly. For the force based rattle assessment the pretension force can be imported as E-line result. The pretension force can be the result of a linear or nonlinear simulation, see Figure 6.

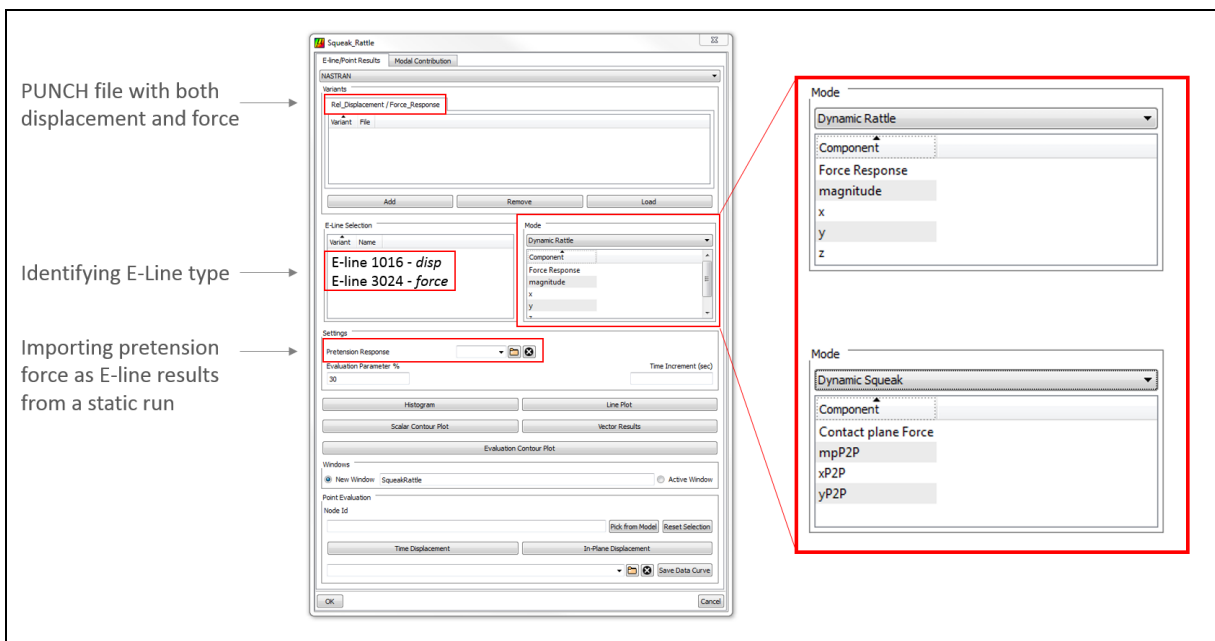


Figure 6 – S&R evaluation toolbar in Meta

5. SQUEAK & RATTLE SIMULATION - TIME VS FREQUENCY DOMAIN

An important question for S&R simulation is whether a time domain or a frequency domain approach fits best to describe the issue [4]. Both the relative displacement and the inner force are the output parameters, which describes the S&R issues. Therefore the closer these output values are to the actual value, the better the analysis is.

The time domain approach gives the actual value right away. In frequency domain the result is represented as amplitude and phase spectrum. Since most of the S&R load cases are transient and not harmonic, the amplitude cannot be taken from the frequency domain approach. The only way to get the actual value, when the results are in frequency domain, is to apply the iFFT, where of course both the amplitude and the phase are considered, see Figure 7. Therefore time domain is the preferred approach, see also upper half of Figure 8.

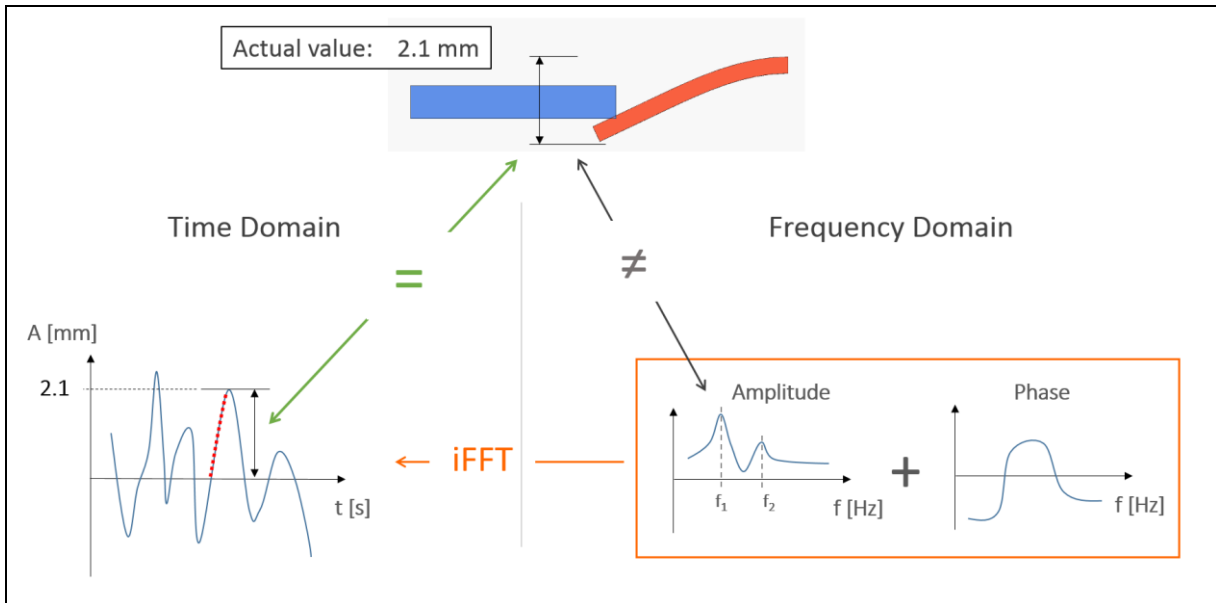


Figure 7 – Time domain vs frequency domain

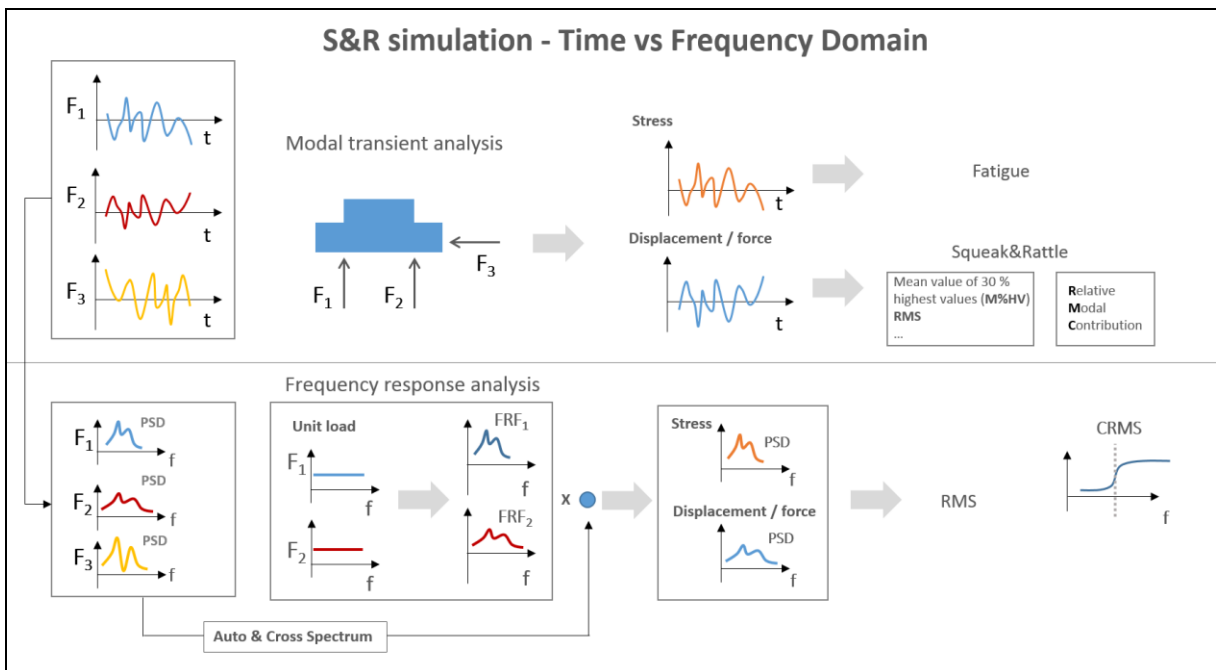


Figure 8 – Time domain vs frequency domain using PSD

In case the time signals of the applied forces have a random character, there is an alternative in frequency domain, see lower half of Figure 8.

The forces are converted to PSD and a frequency response analysis is performed by using unit loads. The FRF outcome from this analysis is then scaled with the PSD loads. So the final results for the displacement and the forces are given as PSD. This is the core process. If several loads are applied at the same time on the structure and if some of them are statistically correlating, the degree of this correlation can be described by the Auto&Cross Spectrum [12]. Based on the PSD results the RMS value can be calculated for the S&R evaluation. Moreover the Cumulative RMS value (CRMS) can be used to identify the critical modes.

But when looking deeper into these features, it becomes obvious, that the results of the frequency domain approach contain in general less information compared to the results of the time domain approach. In addition to that the frequency domain approach is not more efficient simulationwise. Therefore the modal transient analysis fits best to the needs of the S&R simulation.

6. RATTLE SIMULATION FORCE BASED - APPLICATION 1

In general the rattle simulation using the force approach is performed by calculating the operating force resulting from a dynamic road load excitation, which is then compared to a pretension force resulting from a specific mounting process.

First application using this assessment is realized on the lower tailgate trim panel of the LYNC & CO 01 car, see Figure 9.

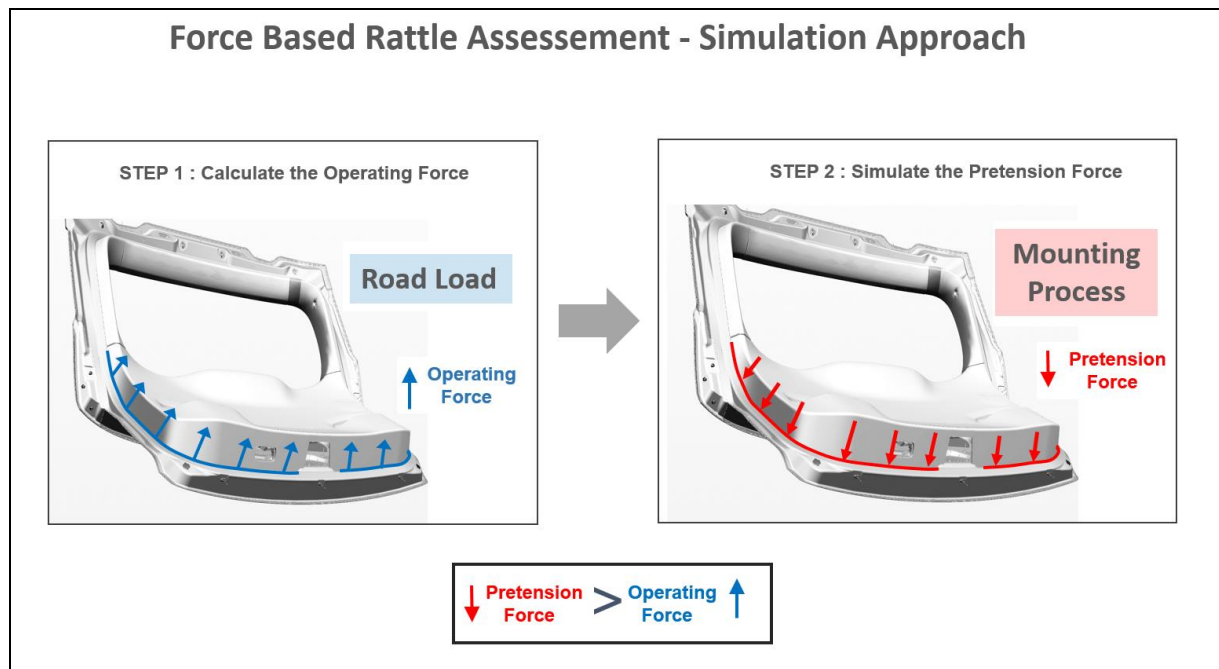


Figure 9 – Rattle force based - simulation overview

For this first application, the principle is to define a reasonable additional mounting force on the tailgate lower trim clips in order to obtain a pretension force along the contact line higher than the operating force coming from the road load.

Complete Vehicle Simulation

When driving the car, the operating force along the line tries to open up the gap between the tailgate lower trim and the sheet metal (DIW). By using a complete vehicle simulation with different test tracks as load, the simulated forces come as close as possible to a realistic load level. Since a complete vehicle simulation gives the most realistic load level, it clearly increases the capability of the S&R simulation.

Basically, the loads are first calculated in ADAMS for different test tracks [1,4]. After that, each one of these forces (up to 100 forces in time domain between chassis and body) is applied to the corresponding location on the body. The evaluation lines (E-line) are then created in Ansa along the gaps where the rattle assesement has to be performed. Finally the calculation is performed using a modal transient analysis in Nastran, see Figure 10.

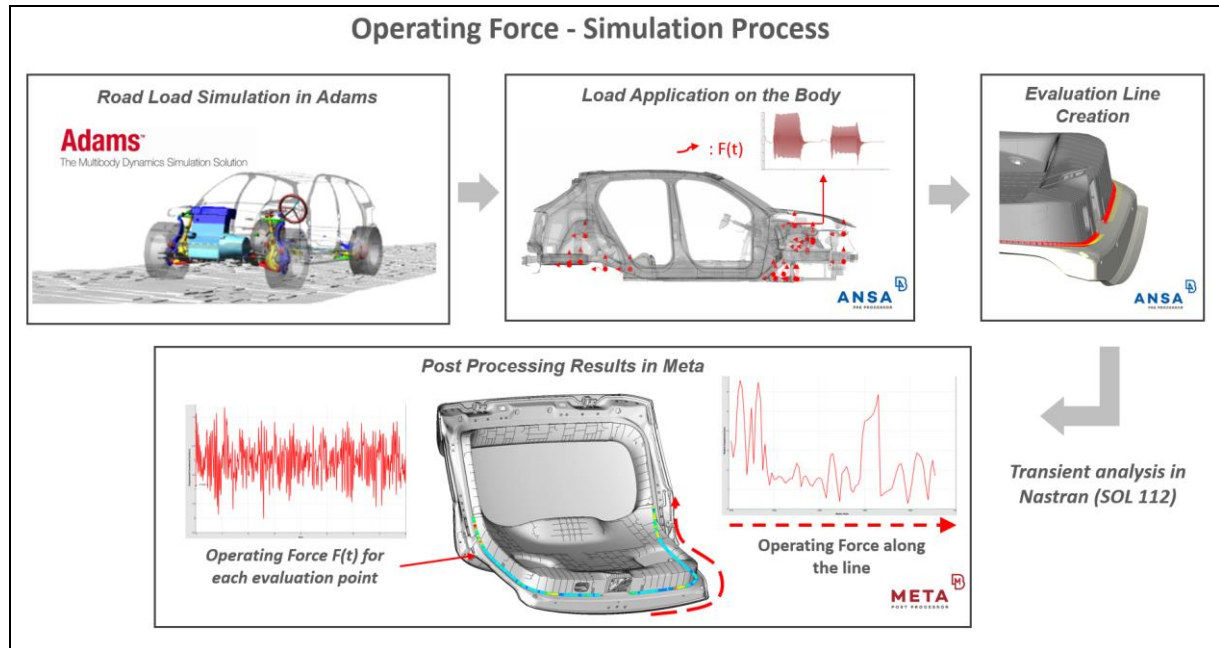


Figure 10 – Complete Vehicle Simulation Process

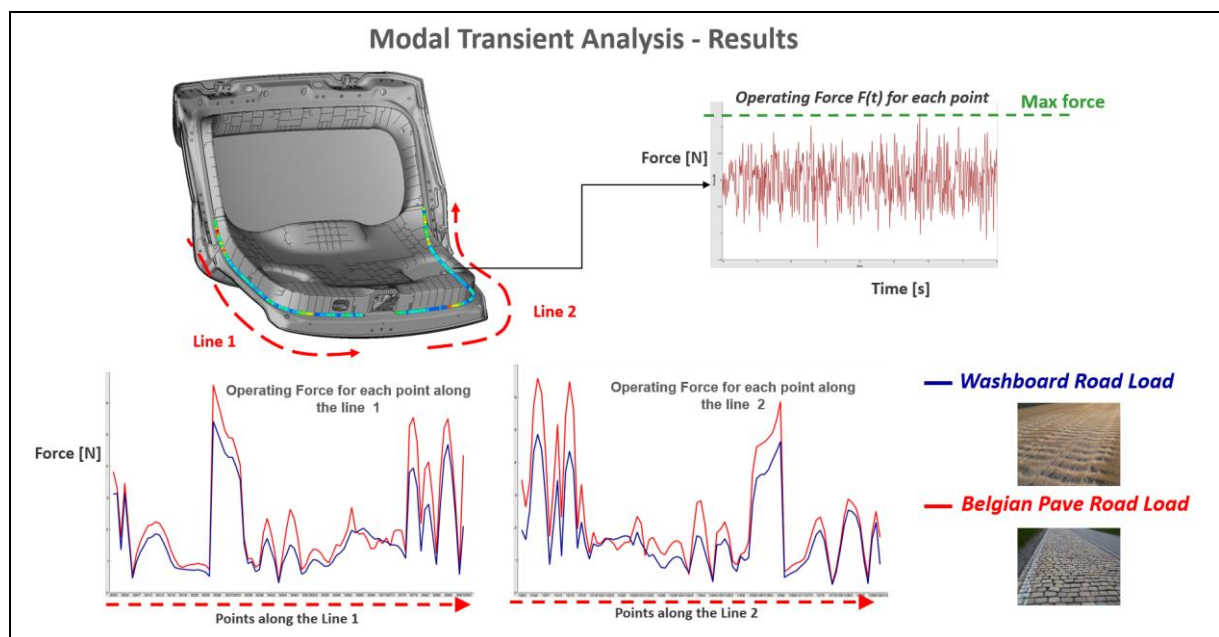


Figure 11 – Rattle force based - post processing results

The results are then postprocessed in Meta by plotting the operating force for each evaluation point in time domain. By using the statistical approach of the E-line method [8], the operating force is postprocessed along the line for different road loads in order to identify the max operating force, see Figure 11.

Pretension force simulation

The second step of the evaluation is to calculate the pretension force along the rattle line. This is done by calculating the force applied by the tailgate lower trim on the sheet metal along the line, when the clips are subjected to an initial penetration. In Nastran, the initial penetration can be set using the CGAP elements, and the calculation is performed by using the non-linear analysis (SOL 106), see Figure 12.

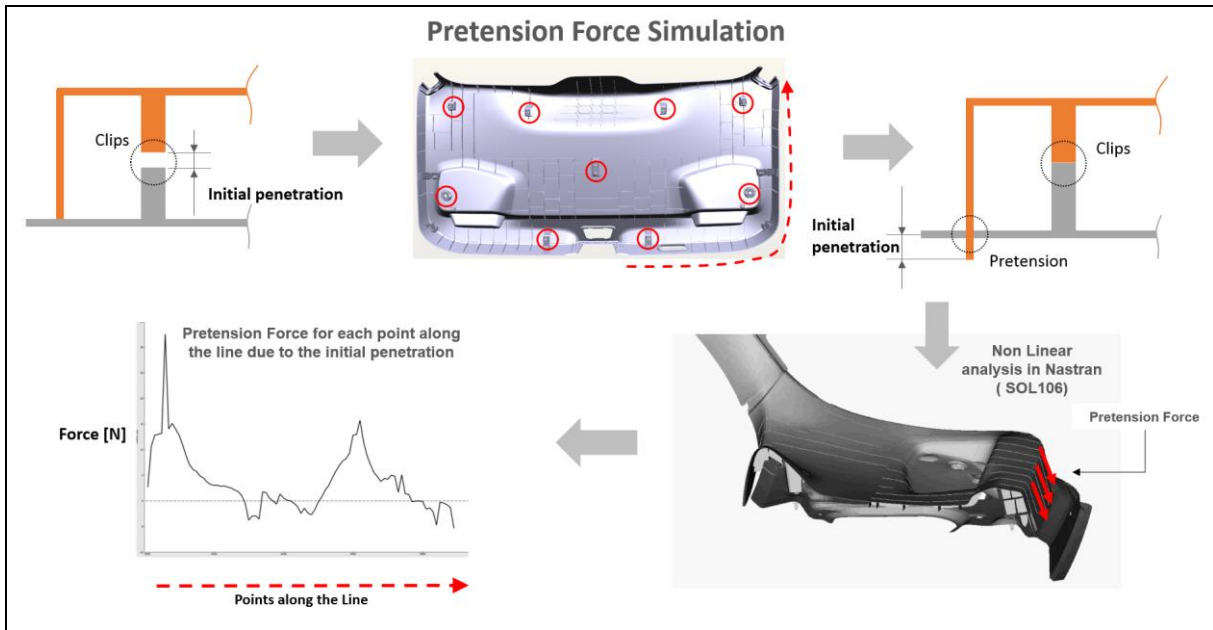


Figure 12 – S&R Force based - pretension force simulation

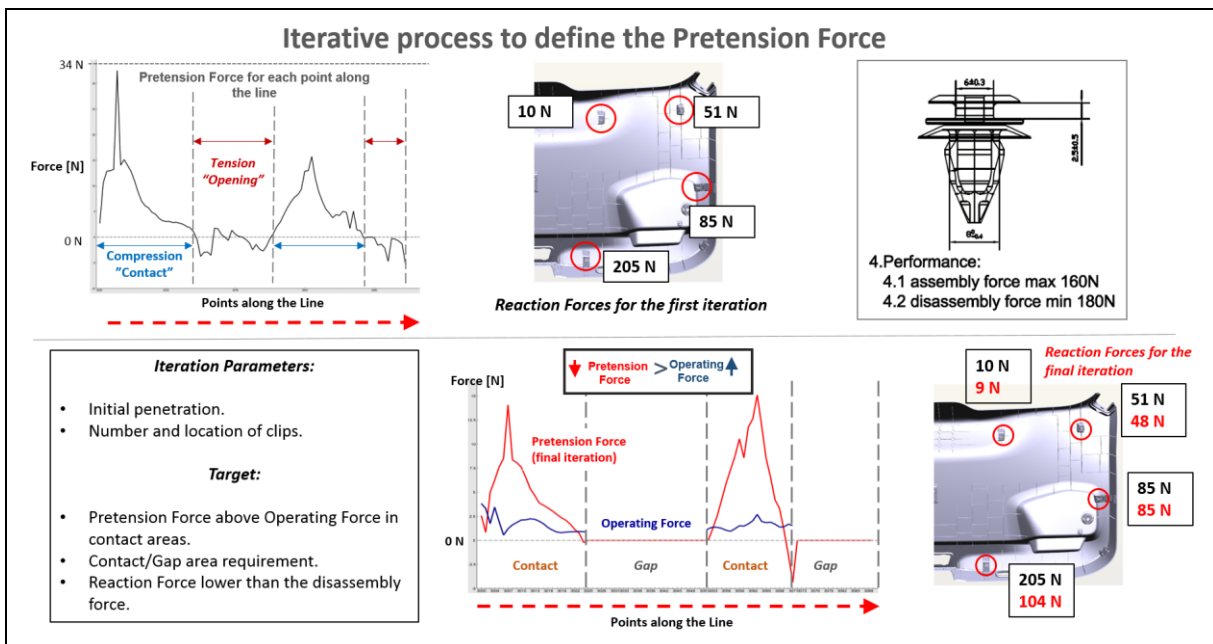


Figure 13 – Pretension force simulation - iterative process

As mentioned before, the principle of the evaluation is to define an additional mounting force that should be applied on the clips to avoid rattle. This is done by performing an iterative process by acting on a variety of parameters such as: the initial penetration input and the number and location of clips.

For each iteration a comparison is performed between the operating force and the pretension force along the line. The process is completed, when a reasonable pretension force higher than the operating force is obtained along the contact line.

During the process, it needs to be ensured that an appropriate gap/contact configuration is defined along the line between the parts, and that the reaction forces are smaller than the disassembly forces of the clips, see Figure 13.

This virtual trimming process is not replacing the real trimming process, but it will shorten it and major tool changes late in the process can be avoided.

7. RATTLE SIMULATION FORCE BASED - APPLICATION 2

A second application is realized on the glove box of the *LYNC & CO 01* car. Instead of the evaluation along a line, the evaluation is performed this time on a point level.

Basically, when closing the glove box lid, the rubber bumpstops are compressed and generate a pretension force on the closing mechanism of the latch. If this force is lower than the overclosing force of the glove box lid caused by driving the car, see Figure 14, rattling can occur in the latch mechanism.

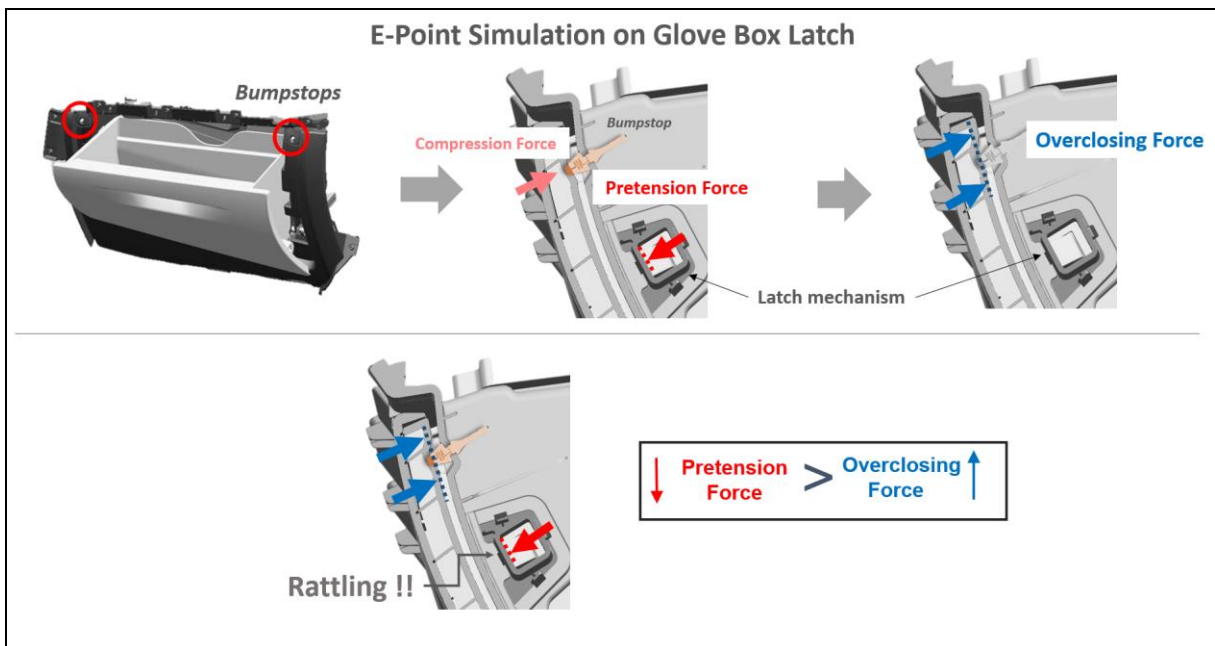


Figure 14 – Force based rattle simulation - Glove box

As for the previous example, a complete vehicle simulation is performed to calculate the overclosing forces on the bumpstops for different road loads.

The results are again postprocessed in Meta by plotting the overclosing force for each bumpstop in time domain. After that, the principle is, to simply define an acceptable compression value of the bumpstops in order to get a pretension force higher than the overclosing force of the lid calculated before. This can be obtained directly from the rubber bumpstop datasheet (force vs compression). This compression value is then to be a design requirement to avoid any rattling risk, see Figure 15. The pretension force thus generated is equal to the closing force of the glove box, which also has to be considered to have reasonable level.

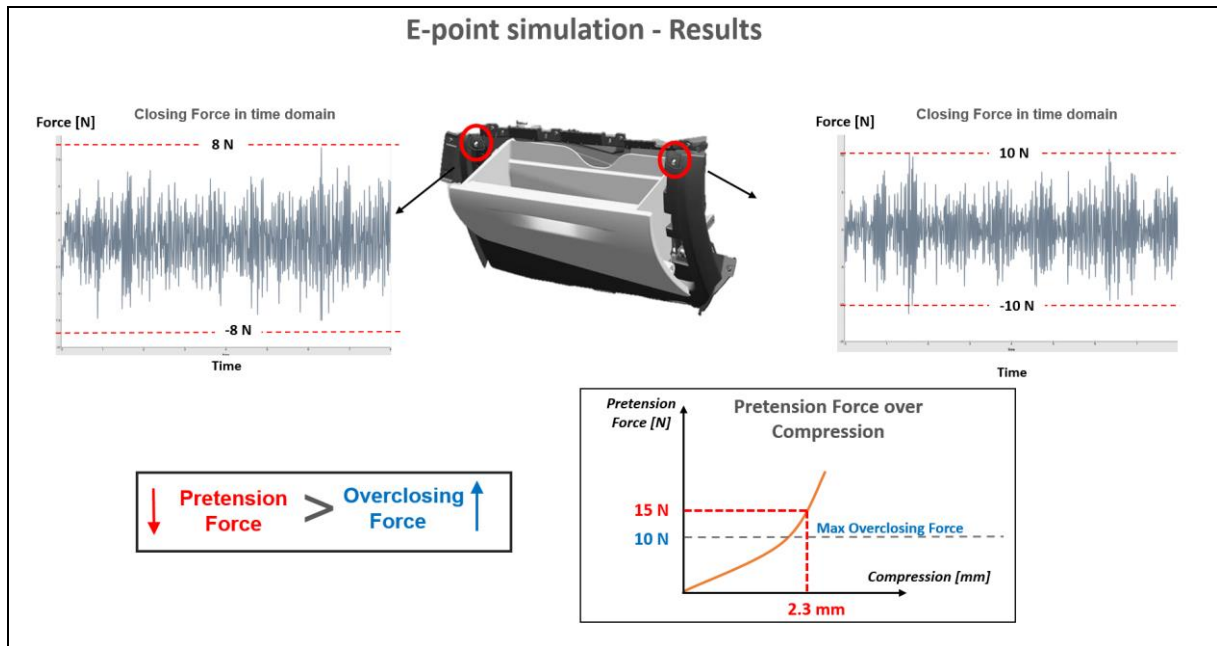


Figure 15 – Force based rattle simulation - Glove box results

8. CONCLUSIONS

The current S&R simulation is a linear approach, which uses the relative displacement for assessing the nonlinear phenomenon of both squeak and rattle. By adding the force assessment this linear approach becomes even more complete and consistent.

In order to assess rattle the pretension force has to be calculated in an extra simulation. According to the chosen pretension concept this extra simulation can vary from a linear static to a nonlinear contact analysis.

For squeak assessment the static friction force has to be tested for the chosen material combination. The test can be performed in a stick-slip test machine or a rheometer. The challenge is to define a procedure, which gives a minimum static friction force.

The new force based assessment is applied on two interior examples, an instrument panel and a tailgate trim panel. Both cases show clearly how the simulation can support the virtual development process to achieve a robust design regarding S&R performance.

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