

Squeak & Rattle Correlation in Time Domain using the SAR-LINE™ Method

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ABSTRACT

A new Squeak & Rattle simulation method was presented at the ISNVH conference 2010 (SAE 201-01-1423). This method, called the SAR-LINE™ method, is based on the evaluation of the relative displacement in time domain due to a random load. A specific challenge for a Squeak & Rattle simulation approach is to correlate the results to a real squeak or rattle phenomenon. This paper presents a new test procedure which enables the correlation between the results of the SAR-LINE™ simulation and the audible rattle occurrence. Three different configurations with increasing complexity were both tested and simulated. A pseudo random signal was used as load and the relative displacement was measured with the Laser Scanning Vibrometer in time domain. The movement in the gap and the rattle sound were recorded in a video sequence. The simulated results along the SAR line can directly be compared with the measured results along the gap. It is shown how the correlation between the rattle occurrence and the simulation results can be performed with the statistical evaluation approach of the SAR-LINE™ method. Beyond this the paper presents also the definition of a new output parameter which can be used for the squeak correlation. The new parameter includes both the time aspect and the main squeak direction which enables the comparison between the squeak occurrence measured with a stick-slip test machine and the simulated results. This type of Squeak & Rattle correlation increases clearly the capability of the SAR-LINE™ method, which is even more important when prototypes are no longer available during the design process.

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INTRODUCTION

Squeak & Rattle issues are always caused by relative displacement, which means, if there is no relative displacement there are no Squeak & Rattle issues either [1]. Therefore, the simulation approach of the SAR-LINE™ method is focusing on the calculation and the evaluation of the relative displacement. In order to bring the simulation approach as close as possible to the real test scenario, a random load in time is used as input signal. In the real world, the critical Squeak & Rattle areas are identified by listening. The simulation approach is instead calculating and evaluating the relative displacement in terms of Squeak & Rattle issues. The specific challenge for the Squeak & Rattle simulation approach is to correlate the calculated results to an audible squeak or rattle issue.

In case of rattle issues, a new test procedure is presented which enables the correlation between the results of the SAR-LINE™ simulation and the audible rattle occurrence. Three different configurations, with increasing complexity, were both tested and simulated. A pseudorandom signal was used as load and the relative displacement was measured with the

Laser Scanning Vibrometer in time domain. The movement in the gap and the rattle sound were recorded in a video sequence. The simulated results along the SAR line can be directly compared with the measured results along the gap. It is shown how the correlation between the rattle occurrence and the simulation results can be performed with the statistical evaluation approach of the SAR-LINE™ method. In case of squeak issues, the definition of a new output parameter is described, which can be used for the squeak correlation. The new parameter includes both the time aspect and the main squeak direction, which enables the comparison between the squeak occurrence measured with a stick-slip test machine and the simulated results.

1. SAR-LINE™ METHOD

The SAR-LINE™ method uses a standard NVH simulation model of the interior or exterior assembly [2]. Since the results of the SAR-LINE™ method are very sensitive to the stiffness representation, a validation of the FE model is important. In case of interior assemblies, a wide range of different plastic materials has to be represented in

the FE model like foam and foil, glass fiber reinforced materials and rubber. In order to improve the stiffness representation of these materials, the modal correlation is an efficient tool. The modal correlation is performed both on a single part level and on the assembly level [3]. In case of light weight plastic parts, it is an advantage to perform the measurement with the Laser Vibrometer. This is due to the fact that no additional mass (accelerometers) has to be added to the structure, and that the number of measurement points is not limited to the number of available channels or accelerometers. Besides the material data, the FE representation of the different mounting points (clips, snaps, heat stakes or vibration welds) is also important to get the correct mode shapes within the frequency range of interest.

After the validation of the NVH simulation model, all the critical Squeak & Rattle areas have to be identified. Since the simulation model is a linear model, the critical areas have to be defined either as a potential rattle area in case of a *gap* or as a potential squeak area in case of a *contact*. Within the automotive applications, these critical areas can be represented in most of the cases by a 3D line in the FE model. The 3D line is defined in between two parts, one of the parts is defined as a *master* and the other as *slave*, see Figure 1.

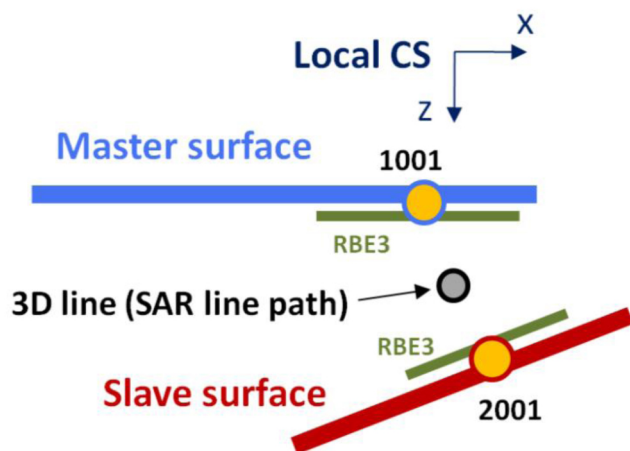


Figure 1. SAR-line definition

The two parts and the 3D line are the input for a TCL script (HyperMesh) which creates the SAR line automatically. Along the 3D line node pairs are created with a user defined spacing, one node is created on the *master* surface, the other on the *slave* surface. The nodes are mesh independent and a local displacement coordinate system for the analysis is assigned to each node pair. In order to capture the local gap or contact geometry the local coordinate system at each node pair is aligned to the *master* surface. In addition, a node numbering convention is a part of the TCL script. This enables an efficient evaluation of the relative displacement, which is the main aim of the SAR-LINE™ method. Since the focus of the method is on relative displacement, an incorrect representation of the gap size or a possible penetration in the FE model do not affect the simulation. This is important

advantage when the method is used in an early stage of the project (see SAR line example in Figure 2).

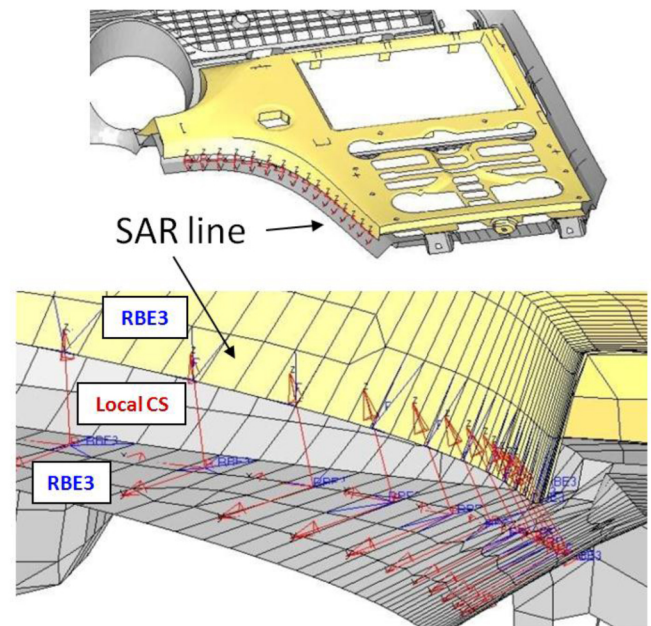


Figure 2. SAR line example

For Squeak & Rattle tests, either a random load or a swept sine can be used. The random load can be defined as a PSD signal which represents a worst case scenario. This type of load is normally used for a test on a quiet shaker table. The random load can also be defined by the measured load on a Squeak & Rattle test track. In order to describe a real squeak or rattle issue (caused by a random load) with the simulated relative displacement, the evaluation in time domain is most relevant, because only in time domain the relative displacement can be calculated [4]. Due to the fact that the load is defined in time, the time length of the simulation input signal is important in order to capture the complete content of the load signal. The modal transient analysis is used to calculate the displacement in the node pairs along the SAR line. The response for each node pair, in time, will be the output of this simulation with the same time length as the input signal. Since the load signal is a random signal, a single peak value is not representative for the response. Therefore a statistical approach is needed to evaluate the response.

In case of a gap line (rattle) the *peak amplitude* of the relative displacement is calculated, and in case of a contact line (squeak) the *peak to peak amplitude* of the relative displacement. The statistical approach to evaluate these both types of amplitudes consists of three steps, see Figure 3. The first step is to rank all the amplitudes. The second step is to choose a certain percentage value of the highest amplitudes. Finally the mean value of these amplitudes is calculated, e.g. M10%HV stands for the Mean value of the 10 % Highest Values.

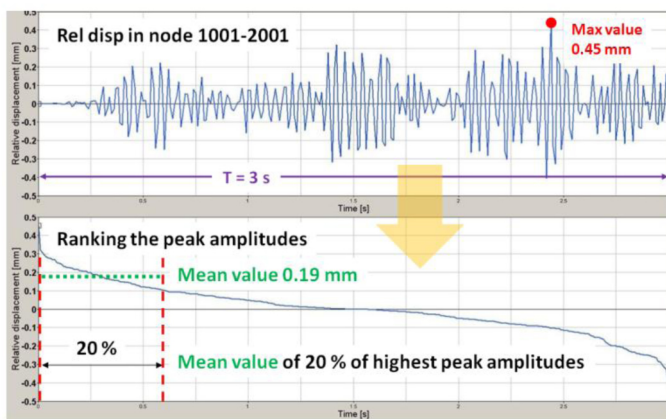


Figure 3. Statistical approach for result evaluation

2. SQUEAK & RATTLE EVALUATION

The calculated relative displacement along the SAR lines can be evaluated on three levels, a global level, a line level and a point level. On the global level, a contour plot shows the values of the relative displacement along the SAR lines, which enables an easy identification of the areas with the highest relative displacement (see Figure 4). In case of a rattle line, the *Magnitude of the Peak amplitude* is shown and in case of a squeak line the *max principal peak to peak amplitude* is shown (see also Chapter 4). All SAR lines are also ranked in a histogram, according to their maximum value.

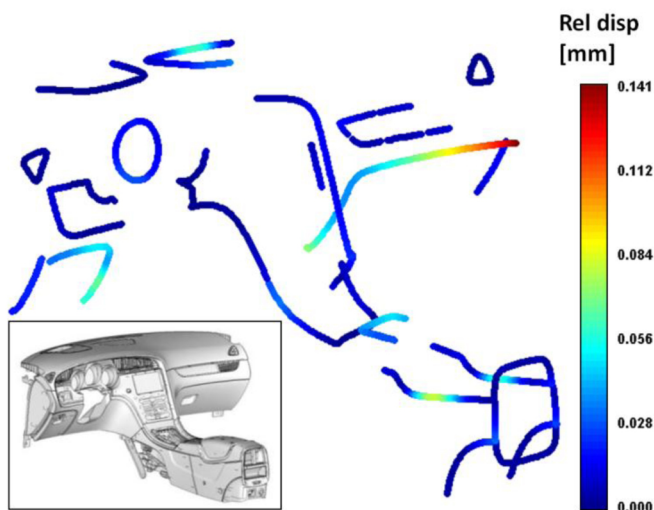


Figure 4. Contour plot along the SAR lines

On the line level, the relative displacement can be studied more in detail for a single SAR line, see Figure 5. The relative displacement is evaluated in each node pair in its own local coordinate system, and it is plotted along the SAR line. In case of a rattle line, the *Peak amplitude* in the local x, y and z directions and the *Magnitude* are plotted. The local z direction corresponds to the rattle direction and is always

normal to the contact plane. The local y direction is always pointing in the line direction. In case of a squeak line, only the relative displacement in the contact plane (x, y) is evaluated. The *peak to peak amplitude* in local x and y directions together with the *Max Principal Peak to Peak amplitude* are plotted (see also Chapter 4). There is no relative displacement normal to the contact plane, which is the local z direction, in which a spring element with a stiffness of 10^6 N/m is defined.

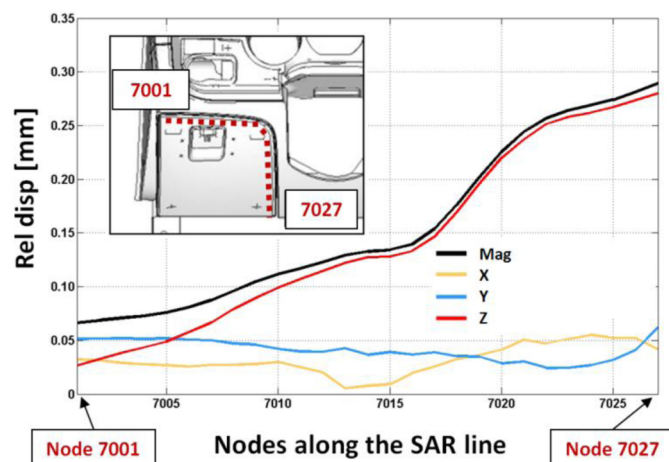


Figure 5. Line plot, result evaluation along one SAR line

Finally the relative displacement can be evaluated on the point level. For a specific node pair, the components of the relative displacement can be plotted in time domain.

These three evaluation features can be used for both an A to B comparison and an evaluation of a rattle or squeak issue based on the absolute values. The A to B comparison can be performed either in a histogram (see Figure 6) or a line plot.

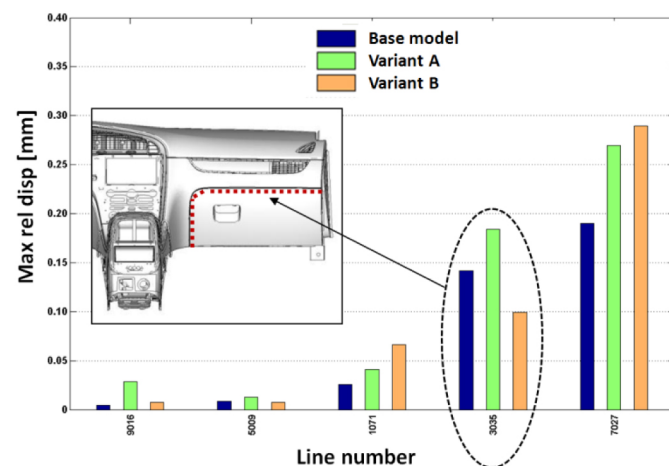


Figure 6. Histogram, A to B comparison (max value per SAR line)

For the rattle evaluation, based on the absolute values, the gap size has to be taken in account, see Chapter 3. For the