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ASSESSMENT OF THE NOISE REDUCTION POTENTIAL OF VEHICLE SHEET METAL BY MEASUREMENT OF THE TRANSMITTED SOUND ENERGY

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ABSTRACT
The reduction of noise radiation of vehicle body components is one of the main tasks of acoustics engineering work for vehicle design. Different measures can be applied in order to improve noise reduction of structure borne sound driven by powertrain, road and wind excitation. While there are a lot of possibilities to improve the structural behavior of body panels, e.g. by sheet swaging, application of ribs or use of damping layers, it is not always easy to clearly choose the best method. A measurement procedure has been established which enables analysis of the total energy balance from input of mechanical energy to the total radiated air-borne sound power. Applicability and benefit of this procedure are demonstrated with a simple test setup. The potentials of noise reduction gained by swaging, ribbing, application of damping layers and elastic decoupling of structures are discussed.

1 - INTRODUCTION
Former results have shown that, in comparison to a monocoque structure as used for most small road vehicles, a ladder-frame (space-frame) structure is able to reduce sound radiation at low frequencies [1]. Therefore a principle test has been designed to more clearly investigate effects of additional ribs/frame structures upon sound radiation and to enable comparison with flat or swaged sheet metal. While the application of bituminous damping layers upon sheet metal of vehicle bodies is a usual measure to reduce radiated sound, some tests have been included into the study. If a ladder-frame structure is used, sound radiation can additionally be reduced by decoupling of the sheet metal with elastic material. The influence on sound radiation has been measured while a silicone fixture was used.

2 - TEST SETUP FOR A PRINCIPLE STUDY
Rectangular sheet metal test objects are fixed with rivets inside a metal frame (tubular steel 30x50mm). This frame is elastically mounted inside a heavy wooden frame (fig. 1a) as part of the test window of a transmission-loss facility (FORD Engineering Center, Köln Merkenich).
Mechanical energy is excited with an electro-dynamic shaker fixed upon the metal frame. The input energy is measured by an impedance pickup (fig. 1b).
The sound radiation of a flat sheet metal (120x80cm, thickness 0.8 mm) is measured as baseline. The influence of several modifications is then tested as given in fig. 2. 4 pieces of bituminous damping layer are used.

3 - DISTRIBUTION OF SURFACE VELOCITY
Data of the panels surface velocity are gained by Laser scanning techniques. This gives an overview of the vibrational behavior of flat (unmodified) and modified sheet metal (fig. 3). Data are here prepared as **"response value" = surface velocity / excitation force** , averaged in the frequency range from 10 to 1000 Hz.
While vibrational energy is equally distributed over the flat sheet metals total area, the spatial distribution is influenced by the structure of frame, ribs and swages. It is remarkable that various ways of

Figure 1(a): Test setup.

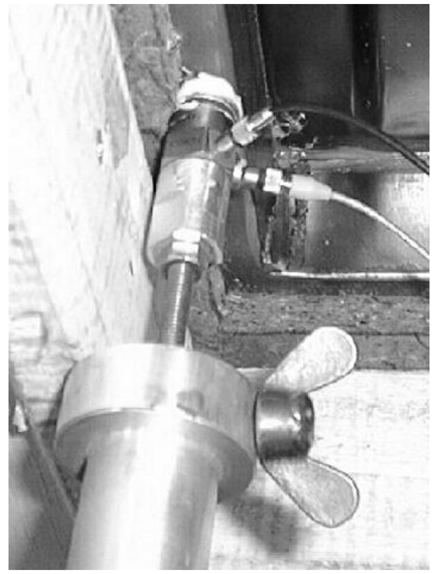

Figure 1(b): Impedance head for measurement of mechanical input energy.

sheet metal modification naturally induce different spatial distributions, but the total energy is rather insignificantly reduced by those measures. Application of a bituminous damping layer, however, gains strong reduction of the vibrational magnitudes irrespective of additional ribbing.

4 - MEASUREMENT OF THE TOTAL ENERGY BALANCE

A measurement procedure has been established which enables analysis of the total energy balance from input of mechanical energy to the total radiated sound power (fig. 4), [2]. An electro-dynamic shaker is driven by random noise. The mechanical input energy is measured by an impedance pickup (fig. 1b), [3]. The total sound energy radiated by the structure is collected inside a reverberation chamber and measured regarding all sound-wave directions and a frequency range of $100 - 1000$ Hz.
Calculation of the **structure-borne sound transmission loss *SB-STL*** describes the energy balance from input energy induced by a shaker to the total radiated air-borne sound energy, recorded inside the reverberation chamber [2].

5 - IMPROVEMENT BY STRUCTURAL MODIFICATIONS

All measured results are related to the structure borne sound-transmission loss of the flat unmodified sheet metal (fig. 5).
The improvement of structure-borne sound transmission loss induced by the modifications described above is shown within fig. 6 for third-octave frequencies from 100 to 1000 Hz. Note that positive values indicate a reduction of radiated sound energy.
The values shown in fig. 7 summarize the total reduction of sound energy within the frequency range $100 - 1000$ Hz. Swaging combined with ribbing here leads to **increase** of sound radiation (!).
Results can be concluded as follows:

- swaging a vehicle sheet can cause small reduction of radiated energy (e.g. total result $<<$ 1dB) but can in contrary lead to improvement of radiation efficiency: e.g. 5dB as 1/3-octave result at 315 Hz
- additional ribs as found at a ladder-frame structure show small reduction of radiated energy, e.g. $<$ 1dB and also can increase sound radiation, particularly at high frequencies
- combination of the investigated swaged panel and the "ladder-frame" ribs causes strong increase of sound radiation (total result $>$ 2dB), in particular above 300 Hz.

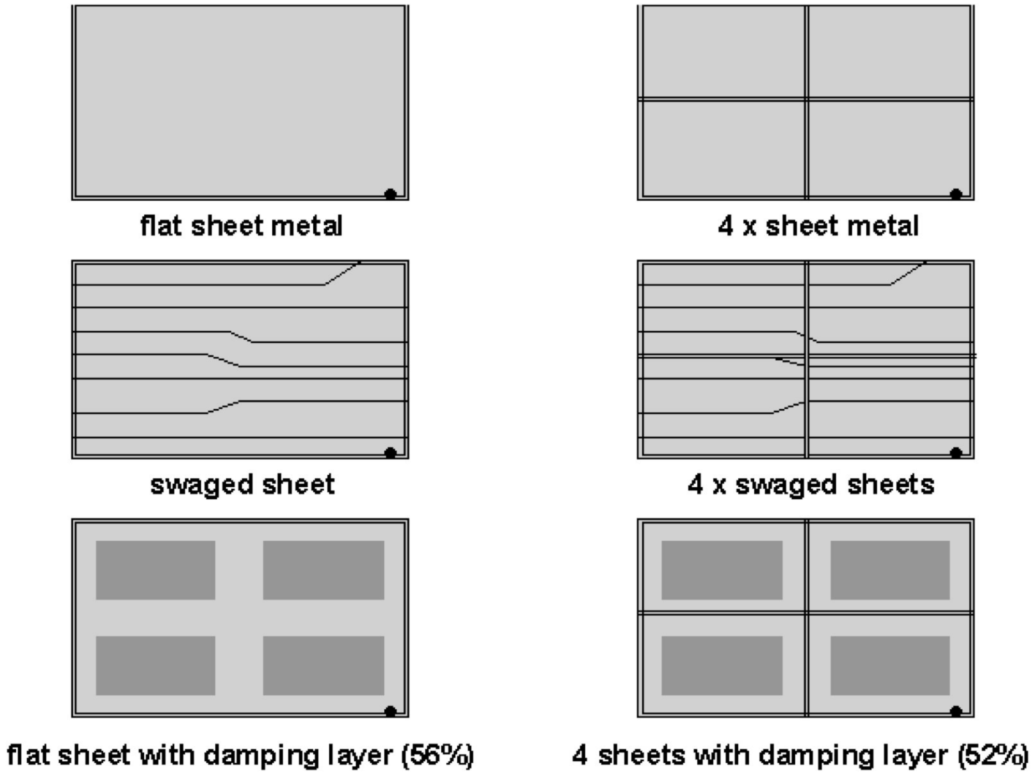

Figure 2: Investigated sheet metal & modifications.

- the only measure that guarantees strong reduction of sound radiation is the application of damping layers, here causing a total reduction of > 3dB. Note that there is **no** 1/3-octave band showing increase of radiated energy.

6 - DECOUPLING OF RADIATING STRUCTURES

Tests described above are done while the panels are tightly fixed upon the frame structure using rivets, thus simulating welding points. Further reduction of sound radiation can be achieved by application of an elastic insulating material between the panels and the frame structure. If e.g. the panels are glued upon the frame by silicone material, the effects of ribbing and application of damping layers are further improved by $2 - 3$ dB. Fig. 8 demonstrates the improvement of the ribbed structure without and with damping layers.

7 - CONCLUSION

If noise radiation of a vehicles body sheets shall be reduced, the application of additional ribs and swages must be handled with care. While the effect of such structural changes depends on the frequency, increase of sound radiation can occur in contrary. Those measures may only be applied if the sound radiating properties of the given structure are comprehensively known. If the structure, however, has not been analyzed clearly, the application of damping layers leads to a guaranteed positive effect (with few exceptions that may occur at singular frequencies). In connection with a ribbed (ladder-frame, space-frame) structure, the noise radiation can be reduced further by elastic decoupling of the radiating structures. Calculation of the energy balance under structure-borne sound excitation proves to be a very effective method to optimize body structures and placement of damping layers.

ACKNOWLEDGEMENTS

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REFERENCES

1. **Kronast, M., Haverkamp, M.** , *Vehicle lower body NVH*, Ford internal publication, 1999

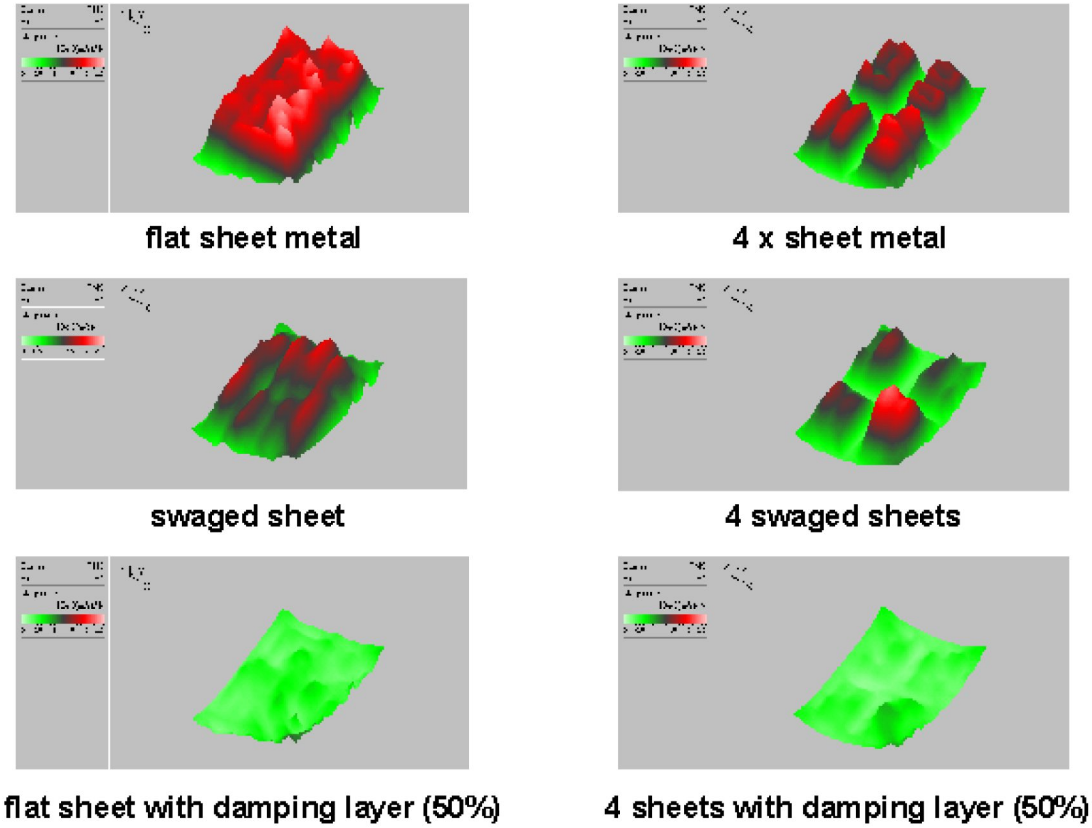

Figure 3: Vibrational behavior of investigated structures: response value measured by Laser scanning technology.

2. **Haverkamp, M.**, Measurement and minimization of the transmitted air-borne- and structure-borne sound energy at vehicle body components, *VDI Berichte*, Vol. 1470, pp. 321-329, 1999

3. **Nath, A.**, *Aufbau eines Prüfstandes zur Messung und Bewertung der Körperschallleistung*, Diploma-Thesis, Aachen, 2000

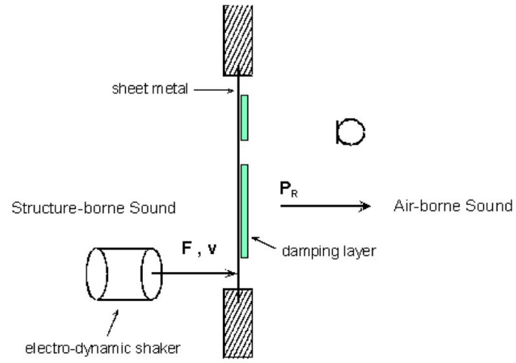

Figure 4: Measurement of the structure-borne sound transmission loss.

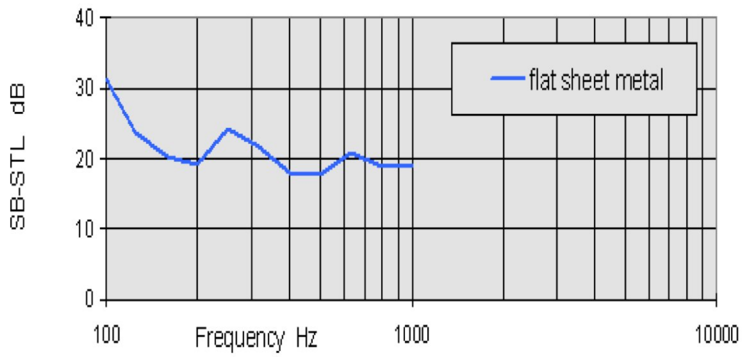

Figure 5: Structure-borne sound transmission loss of the flat unmodified sheet metal.

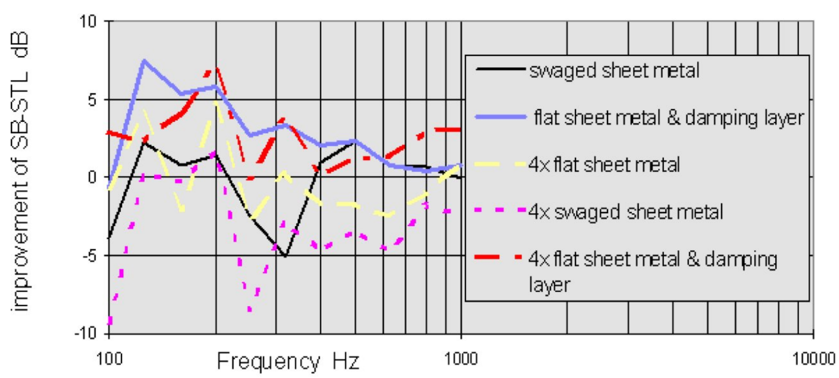

Figure 6: Reduction of radiated energy by swaging, ribbing or application of damping layers (=improvement of structure-borne sound transmission loss).

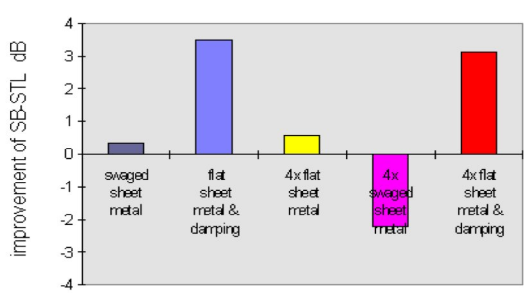

Figure 7: Total reduction of radiated energy by swaging, ribbing or application of damping layers (=improvement of structure-borne sound transmission loss).

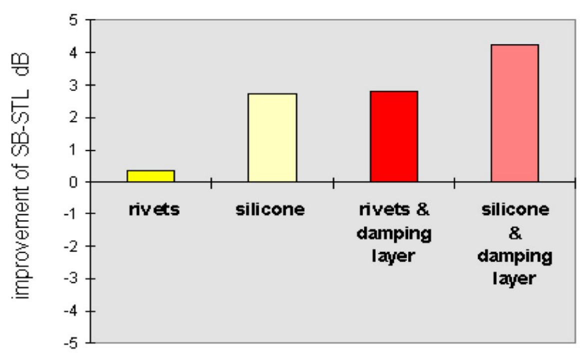

Figure 8: Total reduction of radiated energy by elastic decoupling of sheet metal (=improvement of structure-borne sound transmission loss).