

DAMPING MEASUREMENTS ON TRUCK CAB PLATES

Anders Granhäll

Volvo Trucks
Noise and Vibration laboratory
Dept. 26747 D
SE-405 08 Göteborg, Sweden
anders.granhall@volvo.com

ABSTRACT

When we made measurements to compare the effectiveness of different damping materials, used in truck cabs, we found some unexpected results. The damping was measured with a few different methods and the loss factors obtained varied in the range 1% to 10% for the same damping material.

We suspected that these large variations were caused by the measurement methods and this called for some further investigations.

1. INTRODUCTION

It is always desirable to keep the noise and vibration levels as low as possible in the truck cabs. One of the measures to achieve this is to introduce damping in the cab structure. Sprayable damping material is advantageous from a production point of view and the purpose of the measurements described here was to compare different materials of this type.

When it was considered to change the damping material, the damping properties of the different materials should be tested. The results from different test methods appeared to differ in an unexpected way and this has been further investigated.

2. TEST OBJECTS

The tests were done on two types of objects:

- Oberst test strips: strips of cab plate, ca 10 mm wide and 200 mm long. They were completely covered by damping material.
- Cab plates: four loose sections of a normal cab. All plates were of the same section and the size was ca. 1200 mm by 850 mm. Figure 1 shows the position of the section on the cab. It was standard plates taken directly from the cab production. On two of these damping material was applied in a T-shaped area, see figure 2, ca. 0.102 m² which is 10% of the section area.



Figure 1. Test plates taken from this position on the cab.

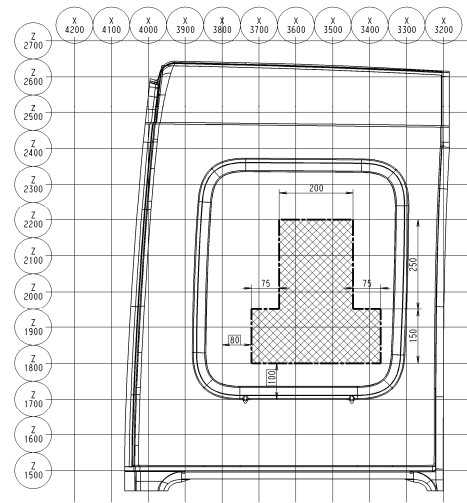


Figure 2. Damping material on the inside.

Two types of damping material were to be compared: INS35 which is PVC based and SP140 which is epoxy based. Both are manufactured by Dow.

3. MEASUREMENTS

3.1. Oberst strips

The damping of the Oberst strips was measured at the acoustics laboratory at SP Technical Research Institute of Sweden, with the resonance bandwidth method. The equipment used was a Brüel & Kjaer complex modulus apparatus type 3930, Hewlett-Packard type 3562A signal analyzer and transducers with conditioning amplifiers. The results are presented in [1].

3.2. First measurement round on cab plates

The cab plates were measured in several ways by Volvo Trucks noise lab. The Volvo measurements are presented in [2].

Before any damping material was applied to the cab plates the reverberation time was measured to ascertain that they were similar.

The measurements were made with impact excitation with an impulse hammer and the reverberation times were measured with a Norsonic 830 third octave analyzer, using the reverberation time option. The calculation methods used is the method described in sections 11.3 - 11.4 of the Norsonic 830 manual.

The following settings were used: Excitation type: IMPULSE, Curve smoothing mode N = 3 and Ensemble mode N = 3.

The result was satisfactory, the plates were very similar and no discrepancies were found.

The reverberation time T_{60} was calculated from the average of T_{15} and T_{30} . Then the loss factor, η , was calculated according to:

$$\eta = \frac{2.2}{f_0 T_{60}} \quad (1)$$

The next step was to apply damping material on the plates. On plate, "A" INS 35 was used and on the other, plate "B", SP 140.

After the damping treatment we decided to use FRF measurements with vibrator excitation. The response was measured with our scanning laser vibrometer.

The FRFs were fed into a modal analysis program for determining the new loss factor.

Damping obtained from the modal analysis program is expressed as a fraction of critical damping ζ and it is related to the loss factor according to:

$$\eta = 2\zeta \quad (2)$$

After these measurements we had results from the following measurements:

- resonance bandwidth tests on Oberst strips
- reverberation time measurements on undamped cab plates
- FRF measurements and modal analysis on cab plates

These results are summarized in figure 3.

In this figure there is also a result for Betadamp (Oberst). This is a constrained layer and gives a much higher damping than the single layers. However, it was not tested on the cab plates. A constrained layer is much more cumbersome to apply in production than a sprayable layer.

A remarkable result is that the cab plates show a much lower loss factor than the Oberst beams and this fact called for some further investigations.

After the measurements we concluded that the resolution was too low (Δf too large) in the FRF measurements.

The needed Δf is dependent on the loss factor, the frequency and the desired number of frequency points within the ± 3 dB limits. In our case Δf should have been in the order of 0.1 Hz but we had $\Delta f = 1.25$ Hz.

However, according to ref [3] this will cause an overestimation of the loss factor so the actual loss factor is even lower than the measured and thus the result is still remarkable.

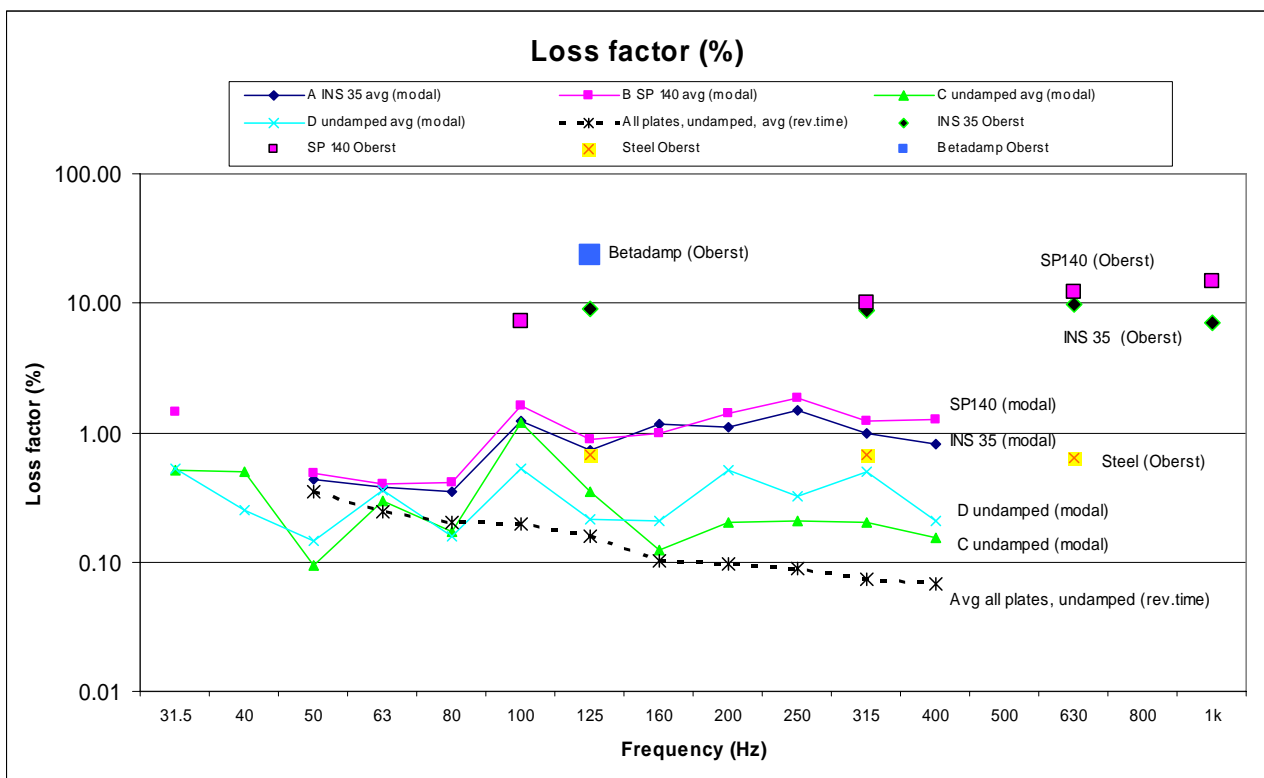


Figure 3. Summary of the first measurement rounds.

3.3. Second measurement round on cab plates

In this situation we decided to measure the reverberation time of the damped plates with impact excitation, i.e. the same method as we used on the undamped plates.

This measurement was essentially a repetition of the first reverberation time measurement but with one more excitation point added, giving two points on the damped area and three points outside it, in total five excitation points. Figure 4 shows the plate. The red marks are the excitation points. The response was

measured with 2g accelerometers in two positions on the rim, one far down to the left and one on the right rim, 2/3 down from the top. The damping material is placed in the T-shaped field, on the back side of the plate.

The white marks are the positions where the FRFs for the modal analysis were measured.

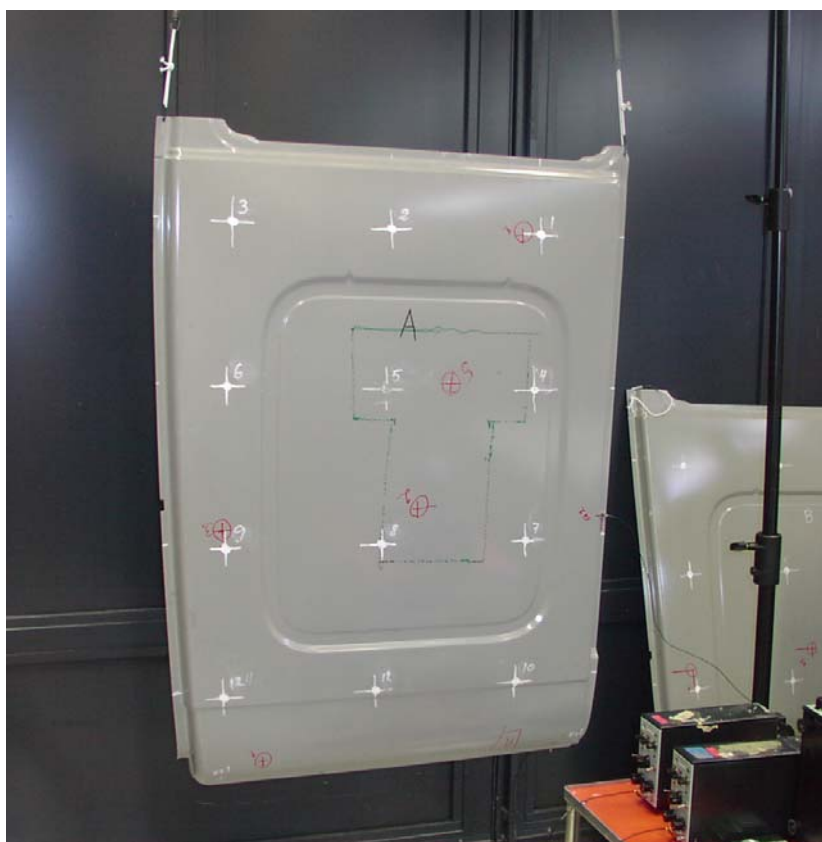


Figure 4. Cab plate, arranged for reverberation time measurement.

The loss factors obtained in these measurements are shown in figure 5, together with the loss factors from the modal analysis in round 1.

As expected, according to ref. [3], the loss factor is higher for the analysis with too low frequency resolution.

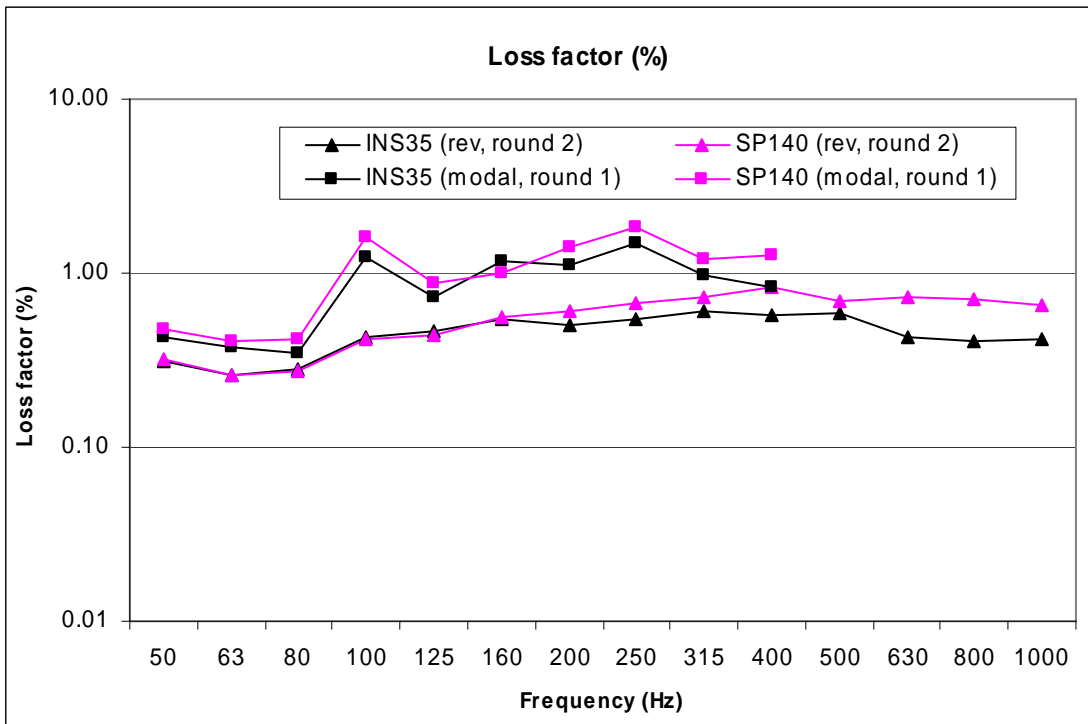


Figure 5. Loss factors for damped plates, both round 1 and round 2.

The reverberation curves were also interesting. Several of them are rather irregular, see figure 6. An explanation to this can be that the rim between the damped area and the edge of the plates break up into smaller areas with separate resonance frequencies, close to each other. The irregularities are caused by interference between these. Similar results can be seen in building acoustics when there are coupled rooms.

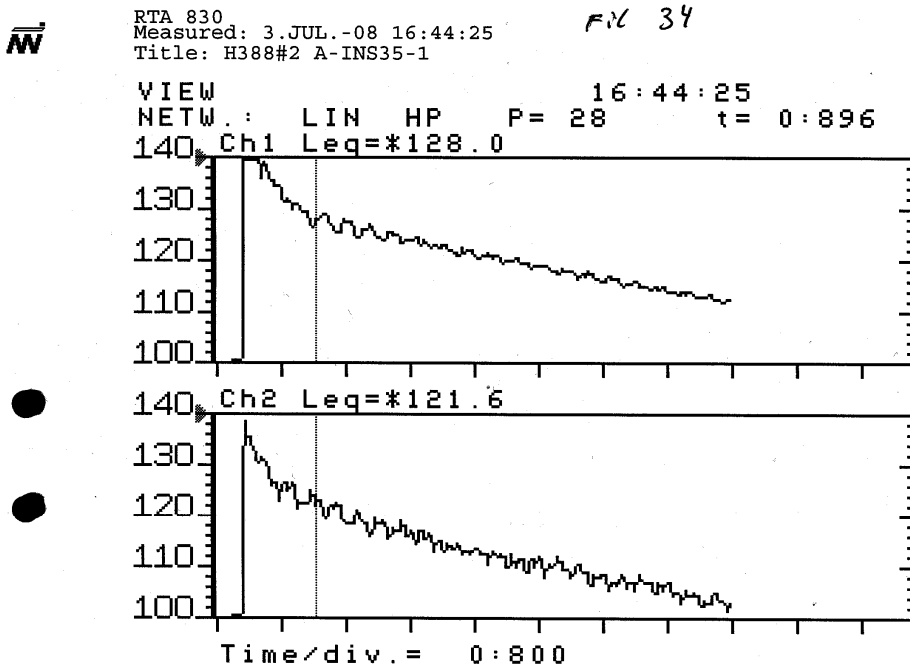


Figure 6a. Reverberation curves, INS35 excitation position 1.

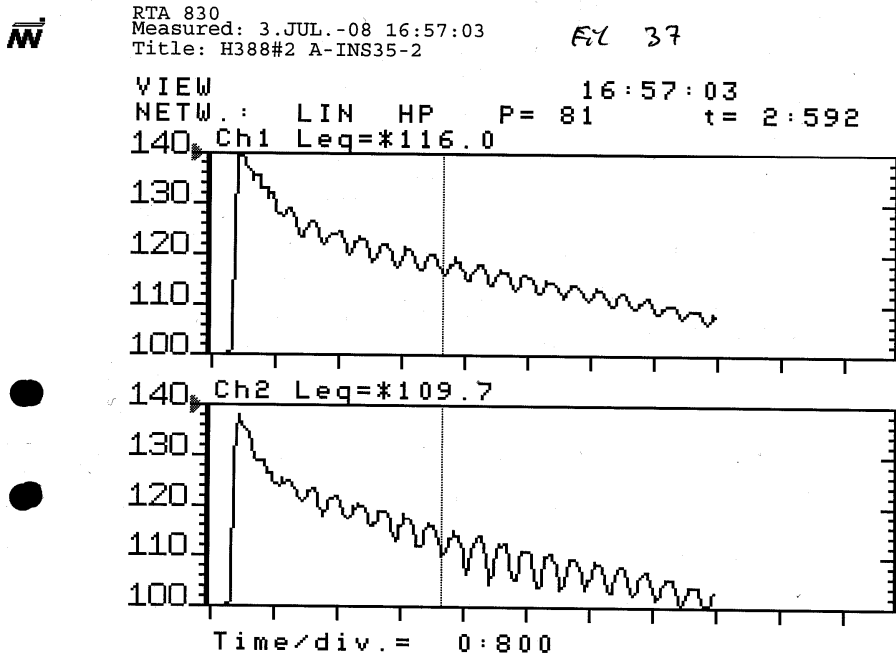
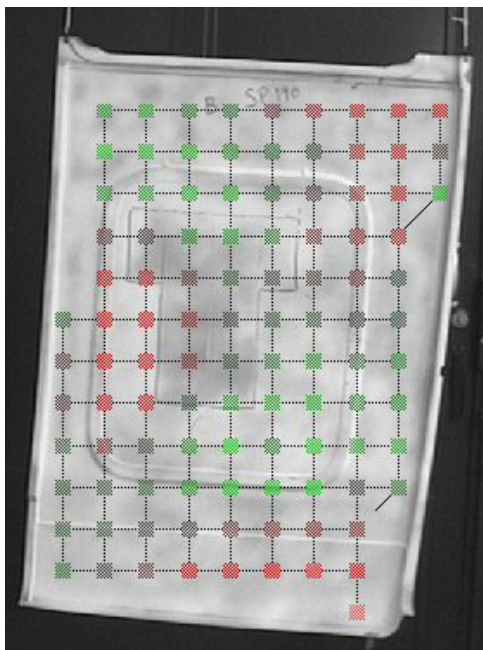


Figure 6b. Reverberation curves, INS35 excitation position 2.

3.4. Measurement of vibration pattern on the damped plates

Another approach we used for studying the behaviour of the damped plates was the use of our scanning laser vibrometer.

This is the instrument used for measuring the FRFs to the positions marked in white in figure 4.



But for measuring the vibration pattern we needed a denser and more regular array of measuring points, see figure 7.

This picture shows the back side of the plate.

The outline of the T-shaped damped area can also be seen.

For one of the undamped plates, denoted by “C”, a typical pattern is shown in figure 8. Of course, different frequencies give different patterns.

The scanning laser software has the possibility of animating the colour maps. In the undamped case the movements of the different areas seems to be consistent back and forth perpendicular to the surface.

However, for the damped plate, “B”, the animation shows a rotating pattern at several frequencies.

One example of this is shown in figure 9. Unfortunately, it is difficult to visualize the rotation in a static picture.

Figure 7. Scan points for measuring vibration pattern.

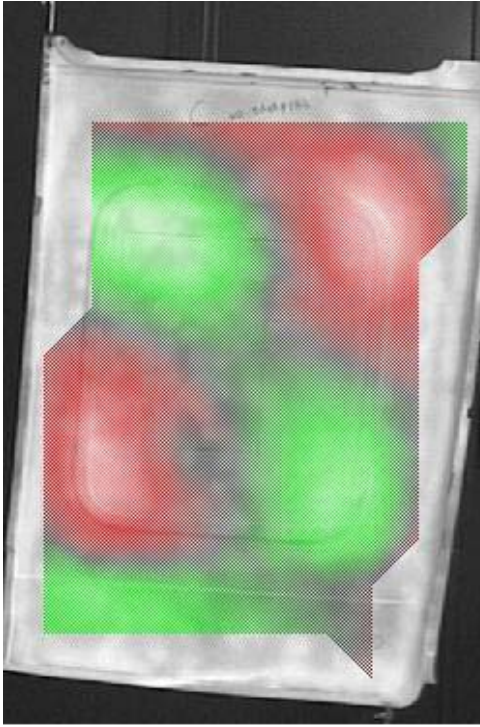


Figure 8. *Undamped plate at 75 Hz*

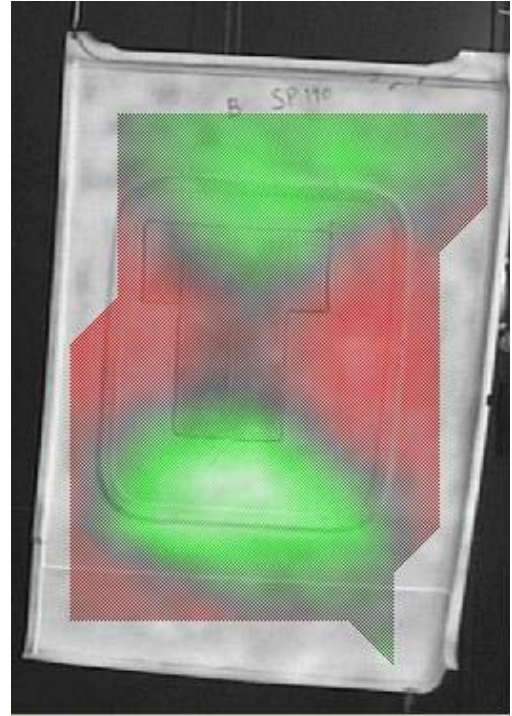


Figure 9. *Damped plate at 66.25 Hz*

4. CONCLUSIONS

The primary aim of the measurements, to rank the damping materials, could be done with both Oberst measurements and with measurements on the cab plates. The ranking was consistent; SP140 gave slightly better damping than INS35 for most frequencies, ca 10 – 20% higher loss factor in average, i.e. the loss factor increasing from ca 0.45% to 0.51% in the reverberation time measurements.

However, the big difference between Oberst and the other measuring methods was a bit more difficult to pinpoint. It is obvious that the cab plates have large undamped areas and it is very likely that these dominate.

The scanning vibrometer measurements indicate this but the picture is not very clear.

Another point is that the free hanging cab plate is very different from the cab plate in its normal situation, i.e. welded to its neighbours on the cab structure, the boundary conditions being completely different.

The conclusion here is that you should not measure in this way. If cab plates are to be measured a complete cab should be used.

If damping materials are to be ranked Oberst measurements should be sufficient.

It is also interesting to use calculation models for optimizing the placement of the damping material on the cab structure.

This has not been studied in this work, but this approach is discussed in ref [6].

5. REFERENCES

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