EUROPEAN COMMISSION
DG RESEARCH

SIXTH FRAMEWORK PROGRAMME
PRIORITY 6
SUSTAINABLE DEVELOPMENT, GLOBAL CHANGE & ECOSYSTEMS
INTEGRATED PROJECT – CONTRACT N. 516288

Optimisation of the powertrain structure by utilising damped load carrying materials

Deliverable no.	D.D15
Dissemination level	Public
Work Package	WP D3, Work task D3.3
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Status (F: final, D: draft)	F_14.02.2006
File Name	SILENCE_D3.3_140206_AVL.doc
Project Start Date and Duration	01 September 2005, 28 months

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1 Introduction

For WP D3, Work task D3.3 please find the following objectives concerning powertrain noise reduction technologies by application of selected damping materials.

Study and selection of suitable state-of-art damping materials considering acoustic and mechanical properties. Realisation of hardware components and implementation on the powertrain structure. Experimental investigations of acoustical properties of powertrain with high damping components integrated in critical structure areas. Demonstration of achievable reduction of powertrain noise emission by testing in an acoustic cell. Assessment of further noise reduction potentials by applying high damping material strategy to further powertrain areas. Estimation of powertrain noise reduction effect on vehicle noise emission on the basis of one reference vehicle.

Work task D3.3 started on 1st September, 2005 (month 8 of SILENCE) and up to now the following work has be performed.

- Acoustic analysis of a 4 cylinder 1,9 ltr. diesel engine
  - Noise radiation of engine
  - Contribution of engine components to total engine noise
- Selection of one noisy engine component (cast aluminium oilpan)
- Application of one highly damped oilpan (aluminium foam oilpan)
- Analysis of noise reduction potential of the aluminium foam oilpan compared to the cast aluminium oilpan

1.1 Detailed description of work performed

1.1.1 Set up of engine including acoustic measuring equipment

The diesel engine was set up in an anechoic engine test cell for operation. In a next step the engine was equipped with B&K transducers for analysing the airborne noise by microphones, the nearfield noise intensity by a double microphone probe and structure vibrations by accelerometers. For analysing the acoustic data a Müller BBM PAK System was used.

1.1.2 Measurements performed

In a first step the 1 m noise radiation of the engine was analysed using 5 microphones (left, right, front, above, below the engine) over engine speed for different loads. In Fig. 1 the average engine noise radiation (average over 5 microphone positions) for three load conditions is shown over engine speed. As can be seen in the mid speed range the part load conditions shows the highest noise level which is quite usual for diesel engines due to combustion excitation.

To get more information on the spectral content of the radiated engine noise a third octave analysis was performed for the different load speed conditions. As an example the 1 m engine noise spectrum at 4000 rpm and three different load conditions is shown in Fig. 2. As can be seen the highest noise levels are radiated in between 1 and 4 kHz.

To obtain an overview of the contributions of all different engine components to total engine noise, a nearfield noise intensity analysis was performed at different steady load / speed conditions. By this nearfield noise intensity analysis a intensity probe is located in 5 cm distance from the engine surface to obtain the exact noise radiation of each engine component. An overview of the engine noise radiation at 1500 rpm part load is shown in Fig. 3. The noisiest engine component is the crankshaft pulley, followed by the noise radiation of all engine accessories combined. The oilpan was found to be the next single noisiest engine component on this engine.

Therefore it was decided to use the oilpan as the engine component to be modified with respect to increased internal material damping for further investigations. A further important aspect for exterior vehicle noise reduction is, that the oilpan is the lowest part of the engine radiating noise to both sides of the vehicle little effected by the shielding effect of the vehicle chassis.

1.1.3 Procurement of a highly damped oilpan

To obtain a highly damped oilpan design it was decided to use aluminium foam instead of a cast aluminium design. From literature and own past research work it is well known that aluminium foam has a much higher internal damping than aluminium castings. Due to this reason a aluminium foam oilpan was procured with the same dimensions as the original cast aluminium oilpan, however with a bigger wall thickness of a approximately of 1 cm, however still with less weight than the original oilpan.

The original oilpan was removed and the aluminium foam oilpan was attached on the engine instead . In Fig. 4 a photograph is shown of the first prototype of the aluminium foam oilpan.

1.1.4 Results of noise reductions using the highly damped oilpan

For analysing the acoustic effect of the aluminium foam oilpan vibration measurements on the oilpan surface, nearfield noise level measurements and 1 m noise level measurements where performed and compared with the same measurements performed on the cast aluminium oilpan.

The vibration behaviour of the oilpan surface was analysed on a number of positions. As an example in Fig. 5 the vibration is shown in terms of acceleration between the two oilpan designs and one can see, that the reduction in structure acceleration is up to 5 dB for the aluminium foam oilpan. In a further measurement the nearfield airborne noise level was measured at different locations around the oilpan in 20 cm distance. One such example is shown in Fig. 6 where we obtained an airborne noise reduction of up to 3 dB over engine speed for the aluminium foam oilpan. To evaluate the effect in the 1 m airborne noise radiation of the engine equipped with the aluminium foam oilpan a number of measurements were performed in 1 meter distance to the left, right, front and under side of the oilpan. In Fig. 7 the improvement of the noise radiation by using the aluminium foam oilpan is shown. It can be seen, that a noise reduction up to 1.5 dB over engine speed can be obtained.

1.2 Further work feasible

A material analysis of the first prototype has shown, that the aluminium foam within the oilpan did not show an optimum structure. It will be attempted to optimise the foam casting process in the next future, therefore it would be possible that a further improved aluminium foam oilpan maybe available in future for the D3.3 work task.

1.3 Summary

The use of a highly damped material (aluminium foam) for an engine oilpan proved to yield a considerable airborne noise reduction potential. This potential is especially effective for vehicle exterior noise reduction since the oilpan is the lowest part of the engine, radiating more or less freely to both sides of the vehicle being little effected by the shielding effect of the vehicle chassis. Therefore it seems useful to further proceed this approach if possible in work task D3.3.

Figure 1: 1 m engine noise level over engine speed

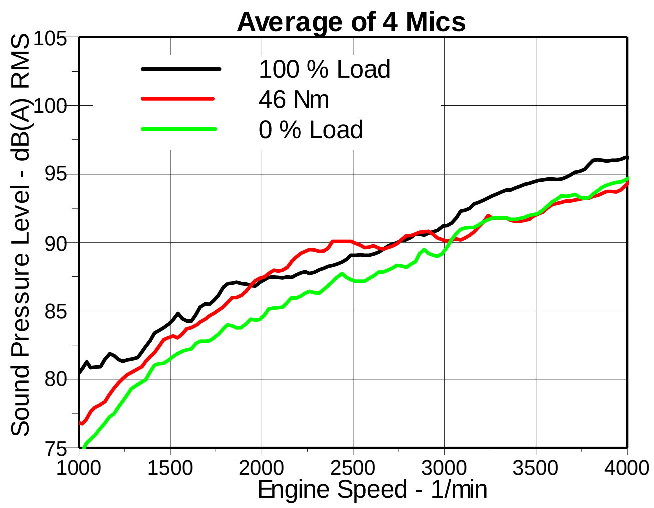

Figure 2: 1 m engine noise spectrum at 4000 rpm

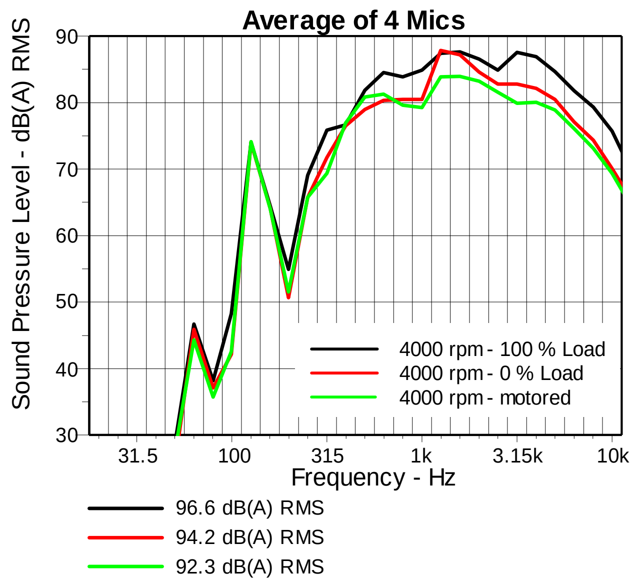

Figure 3: Contribution of all different engine parts to overall engine noise at 1500 rpm, part load

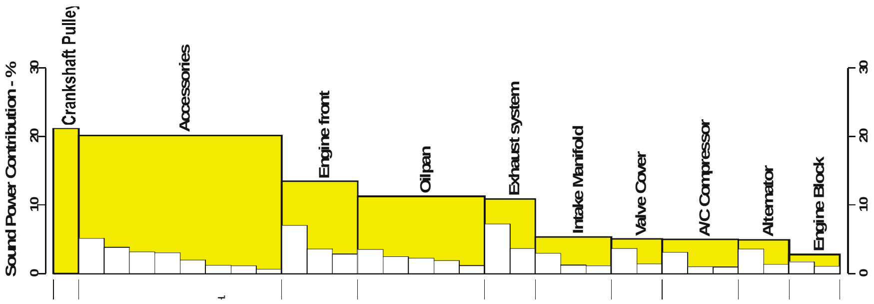

Figure 4: Prototype of a aluminium foam oilpan mounted on engine, ready for testing

Figure 5: Vibration measured on oilpan surface (acceleration)

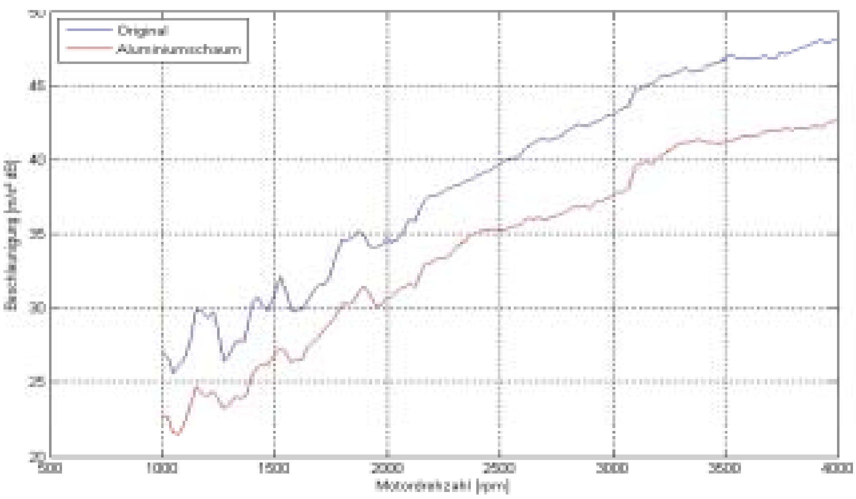

Figure 6: Relative magnitude of airborne noise measured in 20 cm distance from oilpan surface

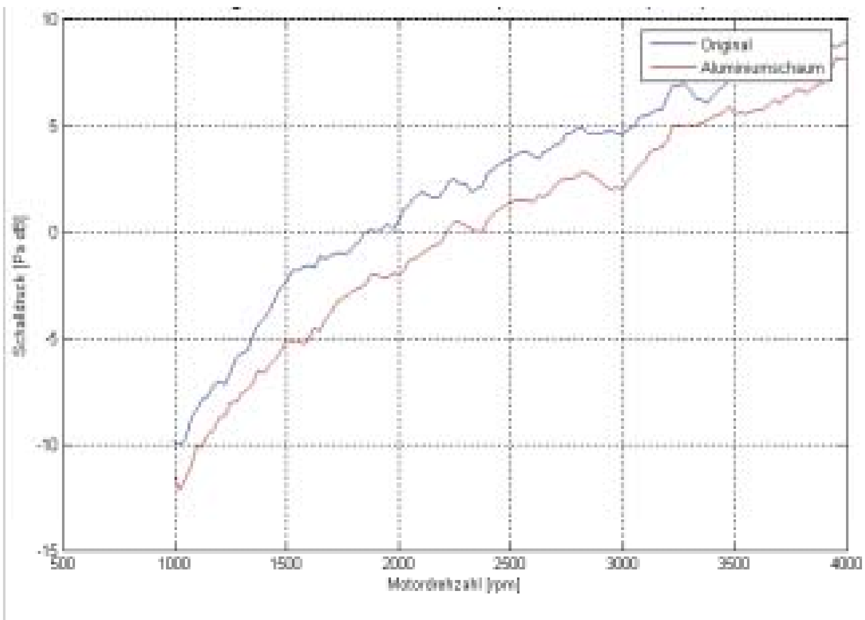

Figure 7: Relative magnitude of airborne noise measured in 1 m distance from oilpan surface