Sound quality design by passive measures in the underbody and the closer engine area

D. Patsouras, K. Pfaffelhuber, Ch. Patsouras

AKsys GmbH

Introduction

By means of passive measures the sound quality of Diesel powered cars can be improved significantly (Patsouras D. et al. 2003). To give an evidence of the efficiency of different absorbing systems in the underbody and the closer engine area, psychoacoustic experiments can be applied. Therefore, the respective absorbing system is mounted at the vehicle and the outdoor idling noise is recorded. In hearing experiments subjects have to make a ranking according to the sound quality achieved by the respective passive measure.

For the present investigations a rear-wheel driven upper middle class car was equipped on the one hand with passive measures in the underbody area and on the other hand an extensive acoustic package in the closer engine area was realized.

Passive measures in the underbody area

The investigated measures in the vehicle's underbody area was a three-part encapsulation (front, middle and rear part). According to table 1, for the three parts various absorbing systems, as chamber absorber, aluminum-membrane-absorber (AMA) or micro-perforated aluminum-membrane-absorber (MAMA), were tested.

Because of its thermal stability the aluminum-membrane of an AMA is quite perfect for the usage of an underbody encapsulation in the area of the exhaust system or the gear box. At this, the aluminum-membrane (figure 1 right hand side) builds closed chambers together with the bridges of the carrier plate (figure 1 right hand side). Those chambers act according to the spring-mass-principle sound absorbing. For the MAMA, the aluminum-membrane is additionally micro-perforated, which leads to an other absorbing effect (Patsouras D. et al. 2000).

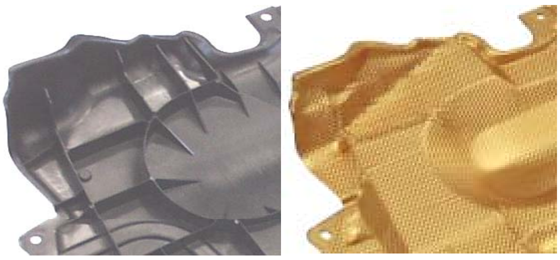

Figure 1: Design of an aluminum-membrane-absorber consisting of a bridge structure (left hand side) and an aluminum membrane (right hand side).

Among the version without any additional absorbing system attached to the carrier plate ("www"), one version completely realized with chamber absorber ("ccc") was investigated in the present study. Alternatively, the rear part of the encapsulation was performed as aluminum-membrane-absorber ("cca") or micro-perforated aluminum-membrane-absorber ("ccm"). Furthermore, a version with micro-perforated front and middle encapsulation was inserted with the hind part consisting again either of an AMA ("mma") or of a MAMA ("mmm").

front	middle	hind
w	w	w
c	c	c
		a
		m
m	m	a
		m

Table 1: Versions of the realized three-part encapsulation systems. w: without any additional absorbing system attached to the plastics carrier plate, c: chamber absorber, a: aluminum-membrane-absorber, m: micro-perforated aluminum-membrane-absorber.

Passive measures in the closer engine area

The three-part encapsulation systems listed in table 1 were realized respectively for the case of the vehicle's standard engine compartment and for the case of additionally attached passive measures in the closer engine area.

Efficiency of the passive measures

The outdoor idling noises of the Diesel powered car provided with the above described passive measures were recorded at different positions in an anechoic chamber.

To evaluate the efficiency of the measures in respect to the sound quality, psychoacoustic experiments were carried out. Therefore, by means of the psychometric method "Random Access" (Patsouras Ch. et al. 2001, Fastl H. 2002) the twelve sounds had to be arranged according to their sound quality from rank 1 (best sound quality) to rank 12 (worst sound quality).

Figure 2 shows the results (median and interquartile ranges) of the 12 subjects for the recordings at the B-pillar. While the unfilled data points symbolize the results of the outdoor idling noises for different versions of the encapsulations according to table 1 without any additional measures in the closer engine area, the filled data points symbolize those with the additional acoustic package in the closer engine area.

Potential of the measures in the underbody area

Regarding the results of the underbody area measures without any closer engine measures, the worst sound quality is obtained without any absorbing system attached to the carrier plate ("www"). Whereas the attachment of chamber absorbers in the whole underbody area results already in a significant improvement, the design of the hind part by an AMA respectively a micro-perforated AMA achieves once more an improvement. The versions “ccm” and “mma” were ranked the same in the mean, however a completely micro-perforated design results in a great leap in sound quality (improvement of four ranks).

Potential of the measures in the closer engine area

The mounting of an extensive package in the closer engine area achieves a complete shift of four to six ranks in sound quality. Thus, the version “cca” *with* the measures in the closer engine area is already judged better (rank 4) than the best one (“mmm”) *without* those measures (rank 5). Similar to the results without the measures in the closer engine area, an additional enhancement in sound quality can be reached by using micro-perforated aluminum-membrane-absorbers (“mmm”) in the underbody area. Hence, the vehicle provided with the three-part encapsulation of micro-perforated aluminum-membrane-absorber with the acoustic package in the closer engine area performs the best sound quality (rank 1).

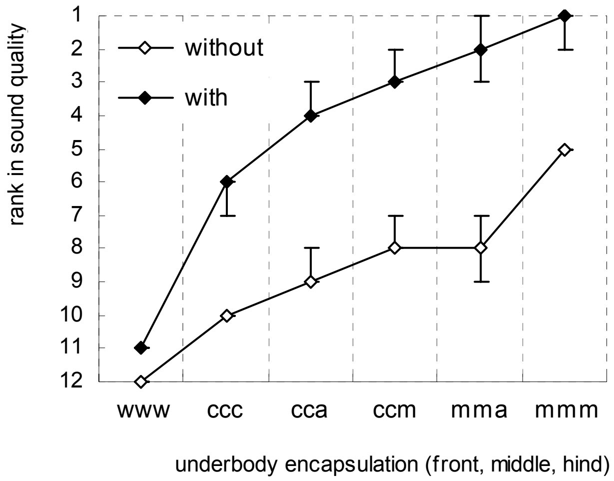

Figure 2: Rank in sound quality for the various three-part encapsulation systems. Encoding as specified in table 1. With (filled symbols) and without (unfilled symbols) additional measures in the closer engine area.

Microphone positions by comparison

While figure 2 shows only the results regarding the recording position at the vehicle’s B-pillar, figure 3 displays also the medians of the psychoacoustic experiments with the outdoor idling noises recorded at the front axle on the right (squares) and the left (triangles) hand side.

A quite good match between the results of those three different recording positions can be observed. The deviations amount maximum two ranks.

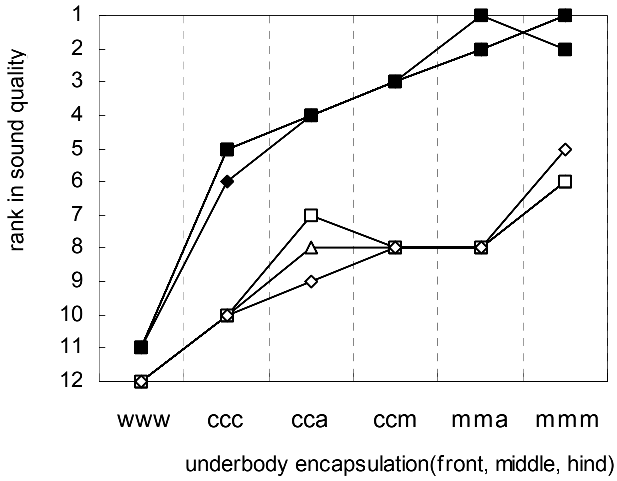

Figure 3: Results of psychoacoustic experiments (medians) of the outdoor idling noises recorded at different positions. Rhombs: B-pillar right, squares: front axle right, triangles: front axle left.

Conclusions

By means of psychoacoustic experiments it could be clearly shown how to improve best the sound quality of the outdoor idling noise of Diesel powered cars of the upper middle class by passive measures in the underbody area. A design of the encapsulation completely by micro-perforated aluminum-membrane-absorbers attained the maximum upgrades.

However, a large potential for improving the sound quality consists additionally in mounting passive measures in the closer engine area which is in particular realizable by means of micro-perforated absorbing systems.

A comparison between different recording positions (B-pillar right hand side, front axle right and left hand side) showed a good consistency regarding the judged ranks in sound quality.

References

Patsouras, D., Pfaffelhuber, K., Patsouras, Ch., Koch, F.: Bauteilkonzepte zur Verbesserung der Geräuschqualität von Dieselfahrzeugen, Daga’03, CD-ROM (2003).

Patsouras, D., Pfafflehuber, K.: Flexible sound absorption by micro-perforation. In: Proc. Internoise 2000 Nice, CD-Rom (2000).

Patsouras, Ch., Fastl, H., Patsouras, D, Pfaffelhuber, K.: Subjective Evaluation of Loudness Reduction and Sound Quality Ratings Obtained with Simulations of Acoustic Materials for Noise control. In: Proc. Euronoise 2001 Patras, CD-Rom (2001).

Fastl, H.: Psychoacoustics and Sound Quality. In: Fortschritte der Akustik Daga'02, EAA-Symposium. Verl.: Dt. Gesell. Für Akustik e.V., Oldenburg, 765-766 (2002).

Zwicker, E., Fastl, H.: Psychoacoustics - Facts and Models. 2nd updated edition. Springer, Heidelberg, New York (1999).