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Acoustic and Thermal Performance Assessment of a Polyurethane based Lightweight Engine Beauty Cover Produced by an Innovative Production Method for Automotive Industry

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Nowadays, for automotive manufacturers, reducing emissions, costs and noise in vehicles is one of the most important issues. Acoustic comfort is a quality parameter that determines the preferences of customers; moreover, noise is a pollution that affects human health negatively. With this approach, the noise absorption capability of all in-vehicle components needs to be enhanced for the acoustic performance that is desired to be achieved across the vehicles. Considering that engine is the one of the most important parts having the capability to creating noise in vehicle, it is critical to enhance the ability of engine covers to absorb noise. Within the scope of this study, the engine top cover, which is an important part for the automotive sector, was produced two-layered polyurethane structure by one-shot. The aim of the study is to make the engine beauty cover produced to be lighter than its counterparts, to provide higher acoustic performance and to obtain a lower cost product. In this context, the products obtained after the design studies; acoustic and thermal properties were investigated.

Keywords: sprayed polyurethane, engine cover, two-layered engine beauty cover, NVH, acoustic

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1. Introduction

Recently, the increased life quality of consumers and demand on automobiles have brought along the environmental concerns and the necessity to satisfy comfort requirement of drivers. Controlling the noise, vibration and harshness (NVH) in the automobile is one of the key criteria for comfort specially to prevent long-term noise exposure related distraction and car accidents [1]. With this respect, engines fitted out with a cover is required as a qualification by automotive industry. Because the engine is the main source of noise in an automobile; therefore, the application of an engine cover not only beautifies the engine compartment, but also suppresses the noise originated from the engine.

Apart from the NVH performance of an engine cover, the material selection is also essential. The use of lightweight material reduces the fuel consumption; hence, the emissions are lowered following the environmental regulations of automotive industry. Moreover, according to "mass decompounding" concept, lighter cars can function with smaller engines without any loss of performance [2]. These two factors make the lightweight materials preferable.

In market plastics, e.g. nylon or polypropylene, reinforced with glass fibers are used as engine cover material. The acoustic performance and heat insulating capacity of such plastics are low. On the other hand, there are engine cover applications of plastics combined with foams or felt having better heat insulation and NVH performance. However, the handicap of these type of materials is that the plastic and foam or felt parts are produced independently and they need to be assembled resulted in a two-step production method. In the study of Siano and his team [3] the comparison of original cover, i.e. nylon skinned polyurethane foam engine covers, and the combination of different choice of materials (basalt wool, thetacell, theta fiber and polyester) having polyamide (PA) skin were evaluated in terms of sound insulation performance, high temperature resistance and cost-effectiveness. As a result of the investigation no substantial enhancement in acoustic performance was observed.

In this study, as the first time in literature polyurethane engine cover having sprayed polyurethane skin and produced one-shot is evaluated acoustically. In this context, a new approach to produce engine covers having similar NVH and thermal performance is presented.

2. Experimental details

Materials and Production

In this study, thermosetting polyurethane was used to form an elastic engine cover having sprayed skin. Production method and the materials related tests were mentioned in previous publication [4]. According to published results this engine cover offered 20% reduction in weight compared to existing plastic engine covers due to its porous structure. Moreover, impedance tube test, conducted according to standard of ISO 10524 – 2, showed that porous structure of polyurethane under the sprayed skin provides superior acoustic damping capacity to engine cover than the commercially available single layer ones.

NVH Performance Tests

To evaluate the NVH performance of this new generation engine cover “Interior Noise Level / Driver Ear Measurements” (according to internal OEM specifications), “Overall Noise Level”, “Engine Radiated Noise / Engine Microphones” and “Acoustic Transfer Function from Engine Compartment to Passenger Compartment” tests were conducted. Samples are named as “Current” and “Proposal”; i.e. “Current” refers to commercially available engine cover, while “Proposal” refers to one-shot two-layer polyurethane engine cover.

Component Tests

Engine cover was subjected to 4 different loop component tests upon the requests of OEM. Dimensional stability (24 hours at 130oC ± 2 °C), thermal cycling (4 hours at 130oC ± 2 °C in oven, 4 hours at 40oC ± 2 °C in Damp Heat Chamber with minimum 90% relative humidity and 16 hours at -40oC ± 2 °C in Low Temperature Chamber), extended heat aging (96 hours at 130oC ± 2 °C) and heat shock test (2 hours at 170oC ± 2 °C) were performed with indicated conditions.

3. Results and discussion:

NVH Performance

“Interior Noise Level / Driver Ear Measurements” were performed by placement of oversensitive microphones to the right ear position of the driver. Both current and proposed engine covers were tested on the same vehicle and Fig.1 showed that the both engine covers had similar interior overall noise level performance. Moreover, the articulation index at driver ear, i.e. the sound quality inside the passenger compartment, were close to each other.

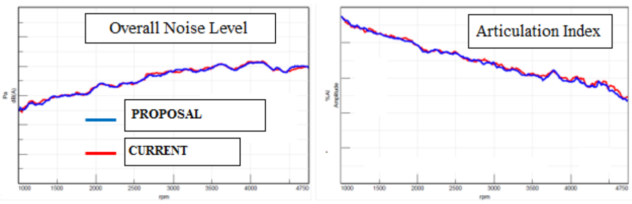

Fig.1: Results of Interior Noise Level / Driver Ear Measurements, “Current” refers to commercially available engine cover, while “Proposal” refers to one-shot two-layer polyurethane engine cover

On the other hand, according to “Overall Noise Level” measurements given in Fig.2, for both covers the overall noise level performance at driver ear and at outside the engine compartment did not present any significant difference.

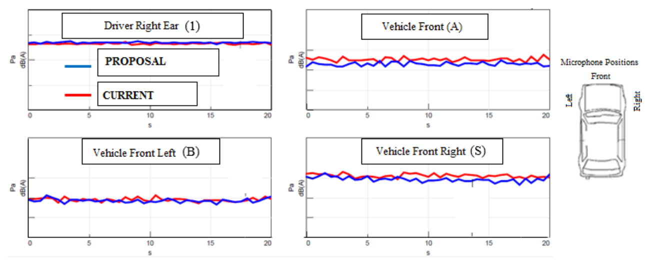

Fig.2: Results of Overall Noise Level Measurements, “Current” refers to commercially available engine cover, while “Proposal” refers to one-shot two-layer polyurethane engine cover

Moreover, the results of “Engine Radiated Noise / Engine Microphones” and “Acoustic Transfer Function from Engine Compartment to Passenger Compartment” measurements were given in Fig.3 and Fig.4, respectively. According to this result, not only the engine radiated noise performance, but also acoustic transfer function from engine compartment to passenger compartment for both engine covers were approximately the same.

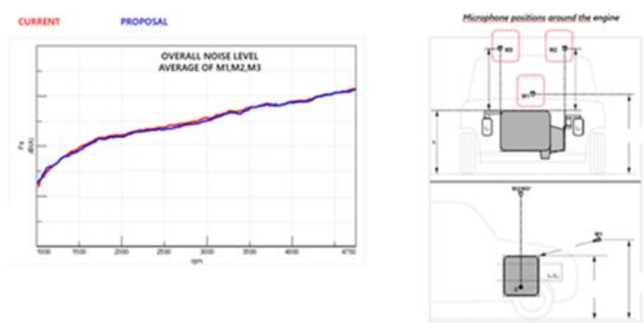

Fig.3: Results of Engine Radiated Noise / Engine Microphones Measurements, “Current” refers to commercially available engine cover, while “Proposal” refers to one-shot two-layer polyurethane engine cover

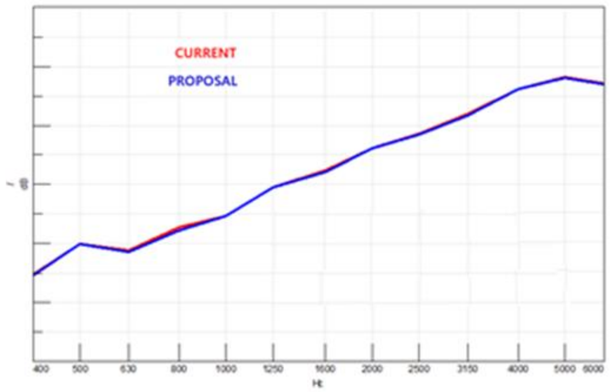

Fig.4: Results of Acoustic Transfer Function from Engine Compartment to Passenger Compartment Measurements, "Current" refers to commercially available engine cover, while "Proposal" refers to one-shot two-layer polyurethane engine cover

In the view of such acoustic data and the previous material related results, i.e. 20% weight reduction with respect to current cover, it was concluded that the proposed cover was favorable.

Component Tests

To simulate the position of the engine cover on the vehicle, both engine beauty covers were placed on the fixture given in Fig.5 and put in the climatic cabin having required conditions.

Fig.5: Engine Cover Fixture Simulating the on-Vehicle Conditions

According to dimensional stability tests, thermal cycling tests, extended heat aging tests and heat shock tests while in the current cover there were not any significant deformation, the proposed one, having two-layered structure, deformed from the front connection areas, presented in Fig.6.

Fig.6: Photographs of Proposed and Current Engine Covers after Dimensional Stability Test, Thermal Cycling Test, Extended Heat aging Test and Heat Shock Test

As the output of the component test, the front connection area was deformed and as the solution of this problem four suggestions were made. Engine fixing points remained same according to base engine design as boundary condition, and the rigidity of the current material and the polyurethane is not the same. Therefore, as a solution the thickness of this section in the part design can be increased; in addition, completely new part design suitable for two-layered polyurethane structure can avoid the deformation. Secondly, increasing the number of connection points could solve the deformation problem. Moreover, within the current design, there is a gap between the cover and the upper surface of the engine. If this gap is eliminated the deformation problem can be solved because the maximum temperature on engine surface is 140°C; on the other hand, the proposed material resists 170°C. Lastly, plastic insert implementation inside the polyurethane cover can be considered as a solution. Further design and experimental investigations are carried out.

Conclusions

In present work the acoustic and thermal performance of a two-layered polyurethane engine cover produced by an innovative one-shot approach was compared with the commercially available one. According to acoustic performance tests, the proposed engine cover, which is 20% lighter than the current one, had the similar acoustic performance with its plastic counterpart. On the other hand, thermal component tests presented that the proposed engine cover showed deformation on the front connection areas due to design related problems, because the materials itself had the ability to withstand up to 170°C. Therefore, further research on the design and implementation on the part are now being pursued.

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