Acoustic Design and Optimization of Automotive Inner Dash Insulations Using Compound Injection Moulding (CIM) Composites.

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1 Introduction

The inner dash insulation is a fundamental component of an automotive acoustic refinement package. Acoustic performance depends, not only, on the material combinations used but also the accuracy of fitment and finish in conjunction with the associated pass-through and ancillaries. As OEM's strive to progressively reduce noise from power units and drive trains it has become necessary to introduce enhanced levels of detail into the design and manufacturing of the inner dash insulation. A popular design uses the concept of a "mass – spring" composite. The mass consists of an impervious high-density layer with the spring made from a porous-elastic spacing material typically using fibres or Polyurethane foam. An extension of this technique used by APG, called Compound Injection Moulding (CIM), allows for the localized placement of mass instead of a uniform distribution.
This paper compares a traditional manufacturing solution with one manufactured using CIM.

2 Acoustic Concepts

The inner dash insulation is located behind the dashboard, or instrument panel, and sits on the cabin side of the bulkhead (firewall) between the cabin and engine bay. It must accommodate the multitude of attached components, such as HVAC and ECU as well as the steering column and operating pedals. Although the inner dash is hidden from the driver and passengers, the ultimate refinement of the vehicle depends on it. Whilst the body-in-white of the vehicle provides an inherent noise transmission reduction depending on the thickness of the construction material (steel, aluminium or plastic composites) and the mass of any additional structural features it is generally too low to provide acceptable noise reduction from high powered drive units. This is irrespective of whether an ICE or Electric drive motor is examined. Introducing an inner dash insulation can significantly enhance transmission loss especially when efficiently optimised. There are different technologies available that are based on different acoustic principles and related weight in accordance with an OEM's specifications along with production volumes and associated costs.
A popular, high performance, design uses the concept of a "mass – spring" composite. The mass consisting of an impervious high-density layer with the spring made from a porous-elastic spacing material typically using fibres or Polyurethane foam. Vacuum moulding of the mass layer, sometimes called "heavy layer" is a traditional manufacturing method. Compounding Injection moulding (CIM) technology allows the effective mass to be adjusted across the surface of the inner dash which enables fine tuning acoustic optimisation, either by testing or simulation. This freedom in design also allows the incorporation of built-in grommet sealing of pass-throughs whilst significantly reducing production scrap rates. During optimisation, the mass value of the CIM layer can also be tuned in combination with a ribbed PU foam "spring". Figure 1 compares surface velocity maps of a vacuum moulded inner dash (left) with an optimised CIM Inner dash (Right) clearly showing the reduction in surface velocity, bluer areas, afforded by the CIM technology. The effect of the CIM Inner dash on overall cabin sound pressure level during a wide-open throttle acceleration in 3rd gear is shown on figure 2 for the driver and front passenger of a 4-cylinder ICE saloon.

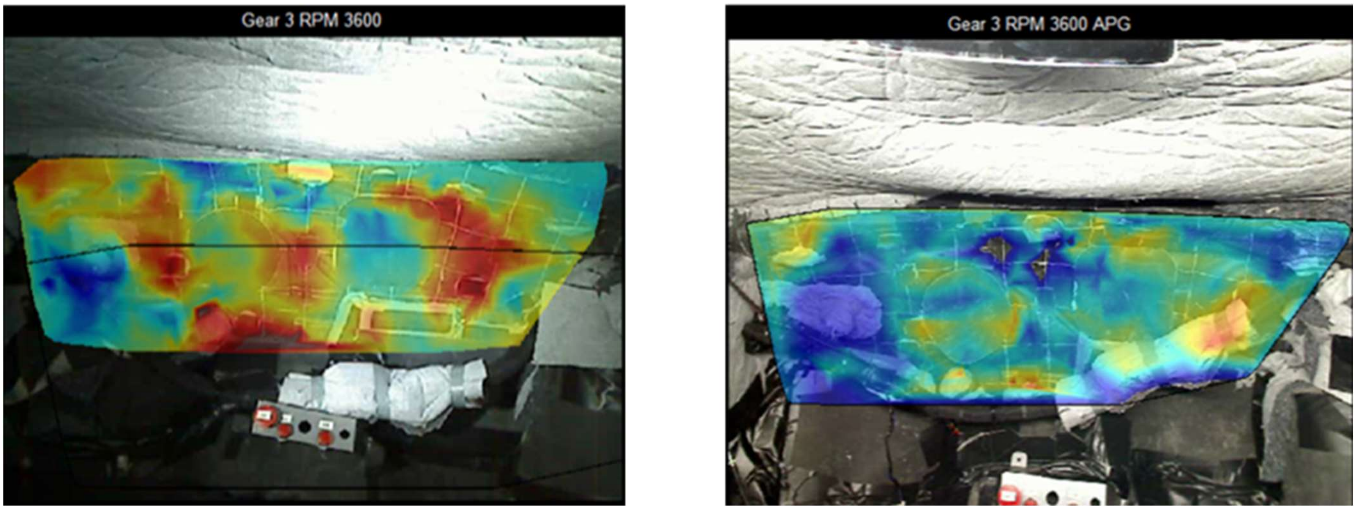

Figure 1 – Surface velocity mapping using "Scan and Paint" comparing Vacuum moulded v CIM technology – average 400 to 2kHz at 3600 rev/min. For a 4-cylinder ICE in 3rd gear.

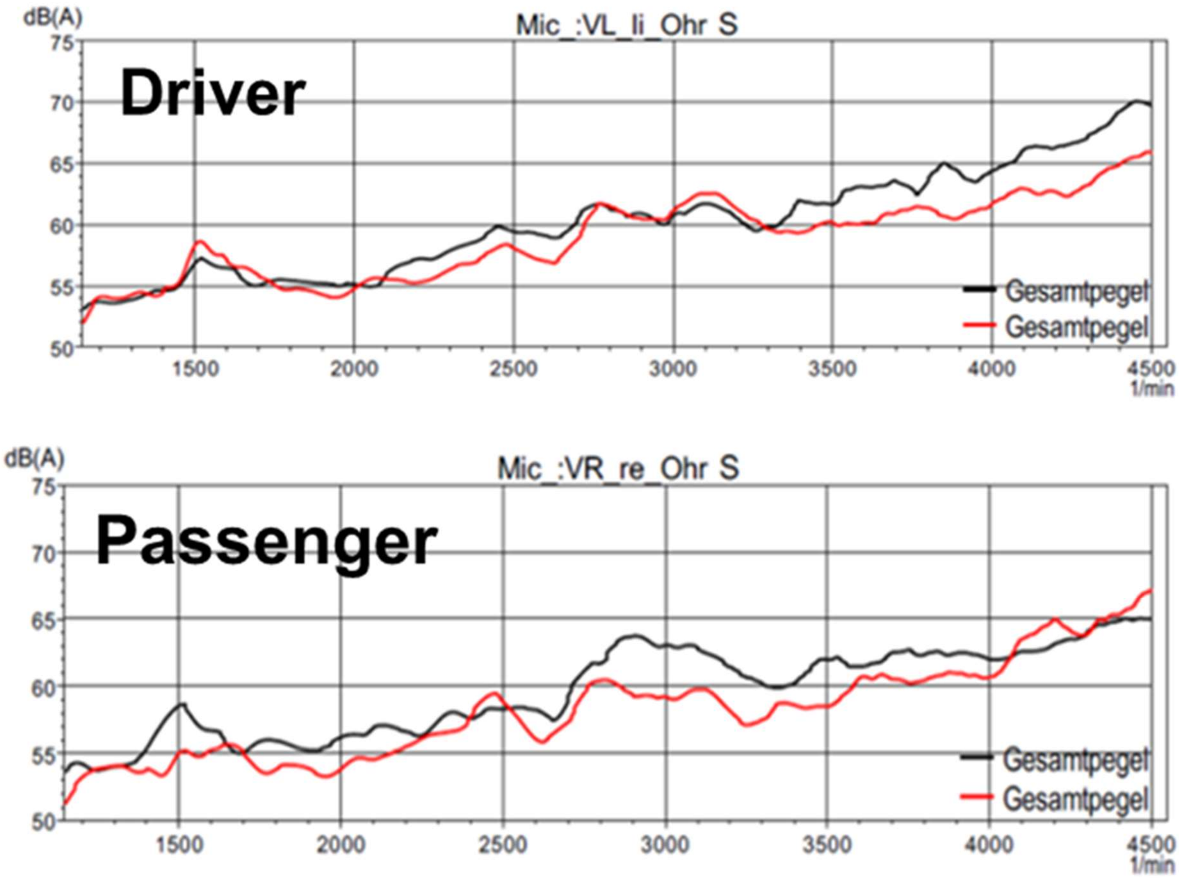

Figure 2 – Overall Sound Pressure Level dBA during 3rd gear WOT (Black Baseline – Red Optimised CIM)

3 Compound Injection Moulding Technology

Traditional vacuum moulding of the mass layer is a simplified version of thermoforming. A polymeric sheet, which is obtained from extrusion technology is heated, usually via infrared radiation, to a temperature close to its' melting temperature and then transferred into a single sided forming tool. The forming process is augmented by applying a vacuum to the underside of the tool and this is held until the material forms the appropriate final shape. Once formed the spring layer is introduced either by in situ foaming or another suitable lamination process if fibre-based materials are chosen. The complete composite is placed on a cutting fixture and perforated according to the vehicle installation requirements. Several constraints are linked to this approach as it deals with a 2-D shape which is converted into a 3-D shape and this often causes stretching of the mass layer sheet which in turn produces local undesirable density variations.

Several years ago, the concept of mass-spring dashes, using vacuum moulding, was transferred to the technically advanced Compound Injection Moulding (CIM) process. This change enabled the inherent advantages of injection moulding (undercuts, ribs etc.) whilst at the same time avoiding the cutting process of vacuum moulding and the associated material scrap rate. CIM is a combination of a typical plastic compounding process with a formulation of specific polymers, mineral fillers, dyes, stabilisers, process aids and fire retardants together with the injection moulding process. It is a one step process which not only saves significant logistic, energy and post processing costs but also enables the mass distribution to be placed according to acoustic optimisation together with associated physical and mechanical requirements.

By using different densities, it is possible to mould parts with different overall weights from the same tool. In addition to this it is possible to significantly vary all parameters of the polymeric mixture. For example, it is possible to vary the final density from 1000kg/m^3 (close to that of a non-filled mixture) to a highly filled compound of up to 2500 kg/m^3, or in case of need higher, and this flexibility considerably increases the potential acoustic performance. The elastic modulus, loss factor and other parameters can also be tailored to the requirements of the final component. Where required the part thickness can be reduced providing considerable design freedom when compared to vacuum moulding technology. In terms of environmental performance, it also allows extensive savings of virgin resources as using injection moulding does not create cutting waste whilst also offering the opportunity to recycle any scraps as the material is a thermoplastic polymer and moreover it allows substitution of adjustment/assembly parts, by integration in the CIM design, so minimizing resources due to reducing material complexity.