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Case Study on Sandwich steel Application in Automotive BIW for NVH Improvements

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ABSTRACT : *In Worldwide Automotive market the migration of customers towards cars having fuel efficient ,compact designs is well established & accepted as an engineering challenge by global automotive OEM.OEMs globally continuously trying to meet customer expectations in vehicle performance criterion. Despite moving towards compact, fuel efficient designs, customers are unwilling to lose many of the vehicle attributes. In which NVH performance is major contributing factor which decides the vehicle performance from customer point of view. Hence, the designer has to ensure that the advantages of a significant weight saving is achieved with proper vibro-acoustics performance. This Paper considers some of the research part of using multilayer damping material in automotive BIW for controlling structure born noise. The study deals with the design, design considerations for sandwich Panels. Design CAE validation, and physical testing along with design optimization of a composite sandwich panel. NVH performance is evaluated using a dedicated experimental setup for the vibro-acoustic characterization of sandwich panels. The predicted improvements in NVH behavior of vehicle are considered for further implementation in BIW design.*

Keywords –*NVH-Noise vibration Harshness,CAE-Computer Aided Engineering, BIW-Body in White*

I. INTRODUCTION

In recent years there is heavy demand for the light weight automobiles in order to meet global environmental & stringent safety norms all over the world. All vehicles must provide protection & comfort to occupants. Comfort & safety is mainly provided by the vehicle cabin compartment. Any vehicle generally consists of body structure (BIW), acoustic treatments & Trims. The main Objective of study is to explore potential benefits of use of constrained layer damping i.e. sandwich material application in vehicle BIW.In the study, the performance in terms of noise, vibration & harshness NVH characteristics & structural requirements of proposed sandwich panels has been examined. Another objective is to identify the application area & specific parts identification for multilayer damping material. Also the Weight reduction & cost saving potential is studied. Fig 1 shows the automotive NVH frequency range. In the frequency range below 500 Hz, the primary source of interior noise is structure born vibration from sources such as power train or suspension system. Booming noise is the name given to the acoustic resonances within a vehicles cabin compartment under frequency of 250HZ. Even very small levels of vibration across large panel areas can cause significantincrease in sound pressure inside a vehicle interior & potentially excite the cavities resonant modes of acoustic vibration. This is major discomfort cause for the passengers inside the vehicle. And for this reason to reduce the structure born noise multilayer or constrained layer damping is used in automotive BIW.Today's automobile manufacturers are keenly aware of the challenges facing the automotive industry in near future. In order to try & achieve some of the mass reductions that will be necessary, manufacturers have already been trying to find areas of obvious mass inefficiency.Worldwide steel manufacturers working with laminates and Composite's engineers to develop BIW parts to meet three goals necessary to the vehicle's overall development: noise reduction, weight reduction, and cost savings.The primary goal was reducing noise for passengers. After extensive testing under a variety of conditions, Silent steel was chosen as a major contributor to reducing structure-borne noise in the vehicle. For example, it scored 95 percent on speech intelligibility testing. This means when the vehicle is traveling at 35 mph, passengers hear 95 percent of audible speech. A 100 percent rating can only be achieved in an insulated, sound-proof room.[4].

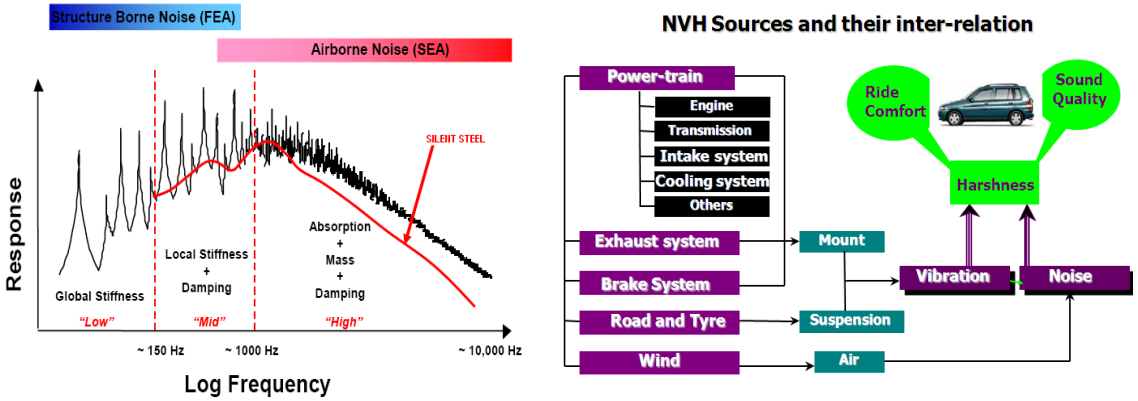

Fig:1:Automotive Frequency Range & NVH Source.

The second goal was to reduce the dash panel's overall weight. Previously, the dash was made of four components: a dash insulator, steel dash doublers, mastic deadener, and steel dash panel and engine side fiberglass dash insulator. When assembled, this dash panel system weighed 12.24Kg.In the new system, only a Silent Steeldash panel and fiberglass dash insulator is needed. This has reduced assembly time and saved space while weighing only 9.07Kg.The direct savings in material cost and reduction in manufacturing and assembly time will help achieve the third goal: overall cost savings. In addition, this lighter weight dash system shouldresult in better fuel efficiency.Silent steel (Sandwich steel) damping material is used since last 15 years in power train applications to control the structure born vibration & noise in vehicle. Ford use sandwich material in major body panels. At GM & Daimler Chrysler underdevelopments include dash panels, roof panels, floor panels, floor pans & trunk floors. [1].Many OEMs using sandwich steel in oil sump applications.

II. ALTERNATIVEMATERIALS

In order to improve overall vehicle NVH performance Automotive OEMs are doing experiments in many areas such as use of alternate materials and different acoustic materials.To understand the concepts & methods proposed herein, it is necessary that reader understand two primary areas of vehicle engineering involved; namely vehicle structures and vehicle acoustics.While sheet metal structures offer excellent performance in terms of, among other things, cost, predictable deformation under impact, and recyclability, they do have negative aspects such as a tendency to corrode, and to be a veritable bonanza of vibratory and acoustic phenomena. [2].Normal Sheet metal is however not the only potential candidate for structural design in modern vehicles. Such material concepts as fiber-reinforced plastics and sandwich structures have long been discussed in the periphery of vehicle design. For various reasons, they have not made a significant contribution tothe structural composition of mass produced modern vehicles. Nevertheless, as the need for a conceptual change surmounts the challenges of implementing such concepts in production, they are likely to become more common in future generations of vehicles.

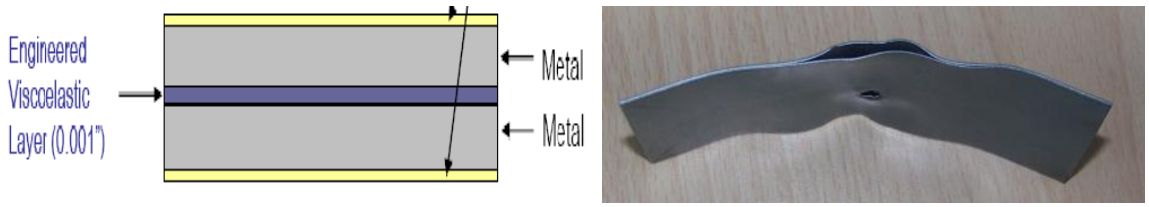

Fig.2:Basic sandwich structure & sheet metal.[7].

Sandwich panel (Silent steel)is a three-ply sandwich material as shown in fig.2 in which two sheets of material are held together by a layer of polymer. Fig.2.also show samples of silent steel material.It shows the most basic form of a structural sandwich. Two thin face sheets of stiff and strong material are attached to a

softer and weaker core material to achieve a sum greater than its parts. By separating the two face sheets with a lightweight material, one can significantly increase the bending stiffness, or flexural rigidity, without significantly affecting the weight. This phenomenon, commonly referred to as the sandwich effect, is only valid assuming that the face sheets are much stiffer, thinner, and denser than the core material. Mechanically, the face sheet layers take up the applied bending loads and moments as tensile and compressive stresses while the core material carries transverse loading predominantly as shear.Metals or fiber reinforced composites are by far the most common materials used for face sheets. [2].Phenomena such as face sheet buckling, global buckling, and core shear failure, face sheet delaminating, and adhesive layer failure must be understood to successfully implement a sandwich structure effectively. Special design consideration must be taken when introducing loads into a sandwich structure or when creating a joint between two sandwich panels due to stress concentrations and other effects. [2].

III. SANDWICH STEEL: CONSTRAINED LAYER DAMPING IN BIW

In any conventional automotive BIW structure the Dash Panel i.e. area in the Engine compartment vicinity requires major NVH treatments in order to avoid the engine noise to come in Passenger compartment. Steel Panel is covered with acoustic treatments and structural foams and cavities filled with acoustic foams. Insulation layer which is molded with PU foam & felt material with approx. thickness of 15-20mm is used for NVH treatment. Insulation layers are covered from inside & outside Passenger compartments.Wheel arches or wheel wells are also identified for the silent steel applications as it is near the tires and gives more vibrations coming from tire movements and drumming sound coming in.[1,3].

Fig.3: Conventional steel automotive dash structure & Silent Steel Dash Panel.

Several different polymer cores available and chosen based on specific application frequency, operational temperature, forming, durability requirements and corrosion resistance of the finished part. Fig.4 shows the application area in BIW on dash Panel. Silent steel eliminates the number of Parts reducing the assembly time. It also reduce the mass and gives major wt saving potential. It eliminates the assembly manpower required. Also it is 100% recyclable.

Guage selection:- Table 01 Show the Silent steel guage selection.Silent steel gauge selection is based on the availability of the formable gauge size with same material properties as that of plain steel panel for YS, TS. Available silent steel sheet gauge is 1.05, 0.9mm thk.

Table :-1:Silent steel thickness.

Average Steel Thickness (mm)	SILENT STEEL Average Thickness (mm)	Average Upgauge (mm)	Average Upgauge (%)
0.92	1.05	0.14	15%

Fig.5 gives the cost & Weight benefits of the silent steel in Dash Panel application. It Indicate the weight & cost saving is main criterion based on the reduction in production time, manpower & Vehicle weight when compared with the conventional steel BIW along with NVH acoustic treatments done in Vehicles.Despite the 30% up-guage, quiet steel provides weight & cost saving as it eliminates the need to use other heavy NVH treatments such as bake on mastic and structural pads.Silent steel up-gauging can be minimized by optimizing part design for the use of laminate early in design stage, thus providing even higher weight & cost savings.

Fig.4:Silent steel application in CAR Dash Panel.

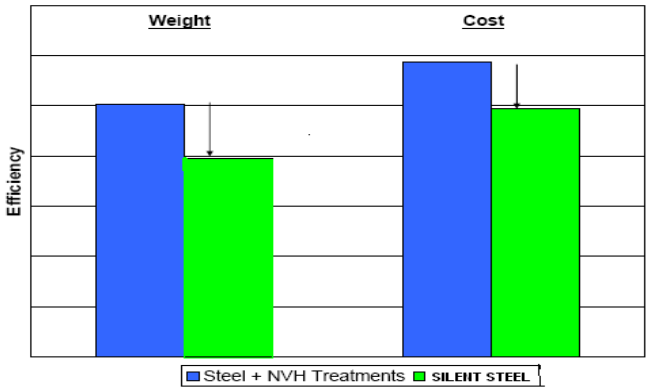

Fig.5:Cost & Weight benefits of silent steel.

3.1 Sandwich steel Dash Panel Performance in NVH

Silent steel i.e. Sandwich steel basically used for constrained layer damping in dash panel, it shows significant improvements in performance indicated in Fig.6. Noise levels inside Cabin when measured shows reduction in noise.[5]. Sound pressure is measured at driver's ear level it is giving improvements by 6dBA, standard steel has 90dBA where as silent steel gives 84dBA sound pressure.[6].

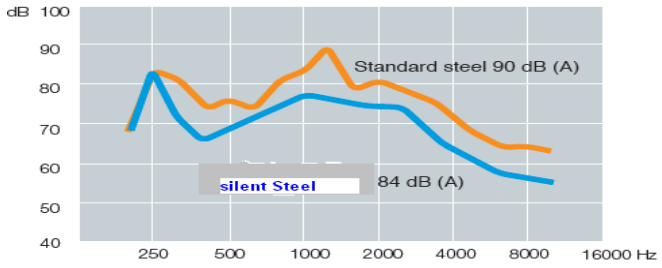

Fig. 6:Sound Pressure level improvements

The acoustic loss factor η is generally used as a measure of the ability to damp structure-borne sound. This specifies the proportion of vibration energy in a steel plate etc. which is converted to heat, and therefore does not generate noise. A high loss factor reduces the vibration level in a structure and therefore reduces the noise given off. An un-damped steel structure has a loss factor of between 0.001 and 0.01. The highest theoretical possible loss factor is 1.0, but a structure-borne damping laminate is to be regarded as reasonable high if the loss factor exceeds 0.1.The properties of all damping material are related to frequency & temperature. Thickness of sheets on both sides are generally same and inner polymer layer is sandwiched inbetween.It depends upon the area of application of the silent steel material in vehicle functional area. [7].

IV. DESIGN CONSIDERATIONS FOR SANDWICH STEEL APPLICATIONS

4.1 Weld ability of Sandwich steel with regular steel:

Tests conducted for the welding feasibility of silent steel with regular normal steel sheets and results found satisfactory for the weld joint performance it is in line with regular steel joints.Different combinations of spot welding & loads are studied and it is observed for tensile loading and spot quality which found in line with regular steels weld joints. Fig.7 shows the silent steel samples tested for the spot welding feasibility with regular steel in BIW.Spot weld joints for silent steel also proves the corrosion resistance in line with regular steel & indicates it's suitability for the mass production.

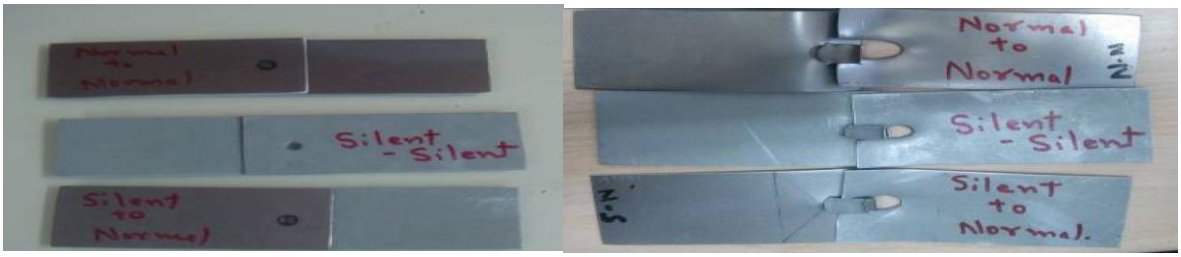

Fig.7:Spot weld Joint Test specimen before & After Tests.

Fig.7.1 indicates the cross section of the spot weld which confirms the homogeneous joining without distortions in weld joints.

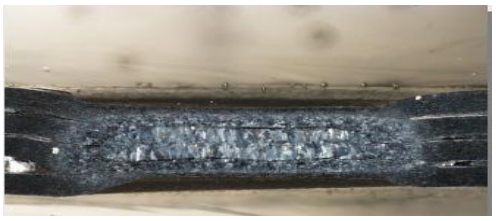

Fig.7.1Cross section of weldjoint.

4.2 Testing of weld joints:-

Spot weld joints are tested for the strength point of view.Test result graph is shown in Fig.8.Total 5 No spots tested for different tensile loads .Test gives the results & confirm the use of silent steels in BIW. Vehicle level performance of the BIW with silent steel is to be analyzed physically.

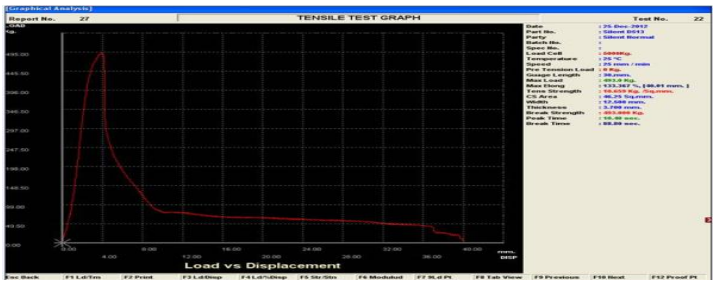

Fig.8.Spot welding Test Set Up & Results (Load Vs Displacement)

- Silent steel leads itself readily to spot welding and seam welding.
- The strength of the joints being equivalent to the normal strength of joints in solid steel sheets.

4.3. Corrosion Resistance & Part Manufacturing feasibility:

Joints between silent steel & regular steel withstand the salt spray tests conducted to evaluate the accelerated corrosion test for weld joints & material. Polymer being the content between two sheet metal layers it should withstand the corrosion resistance. It is another main requirement Part CED & Paint process must be in line with regular steel &found to be equivalent with conventional steel.[7].

Also Parts manufacturing feasibility is done for the parts designed with material silent steel. For parts manufacturability parts should be free from sharp corners, smooth transitions in shapes has to be there in order

to avoid thinning & wrinkles on parts.Fig.9 shows the actual design part & final part design after forming simulations.[7].

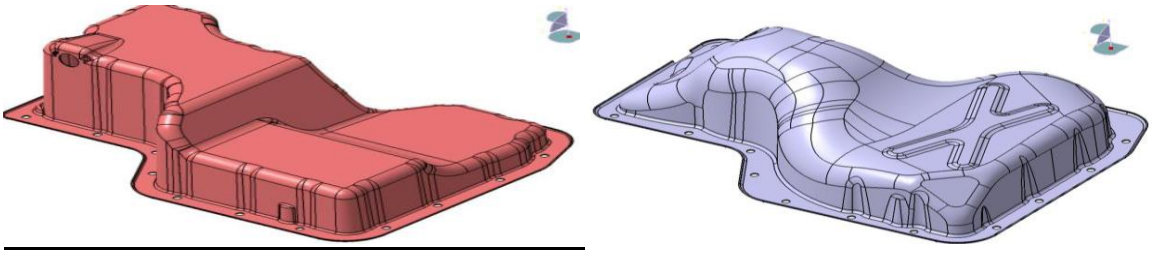

Fig.9:Initial Part Design & Final Part

V. CONCLUSION

Sandwich steel use in automotive BIW gives improved NVH performance compared with regular steel. Its manufacturing is in line with conventional steel & no separate investment is required for implementation.It gives approximately 6dBA reduction in sound pressure compared with regular steel. It is observed in CAE results &physical validation is to be conducted to evaluate performance on vehicle level. Sandwich steel has its limitations as availability of the material in India which will be main driving source from cost point of view for l application in automotive BIW. Sandwich steel gives improved performance by reducing the manufacturing time, cost & weight. Worldwide laminates manufactures are focusing research on sandwich steel which will give it better edge in more areas for automotive applications.

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