Thickness determination of SMC replacing Sheet metals for Automobile roof

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ABSTRACT : *Sheet Molding Compound (SMC) is used in automobile body panels for weight reduction instead of sheet metal. As an alternative material SMC must fulfill the strength requirement as well as contribute less weight to Body-in-white (BIW). Hence, its thickness selection must be done strategically. In this paper, the degree of experiments (DOE) technique was used to determine the suitable thickness of SMC that can replace the traditional sheet metal roof in automobiles. In DOE technique, a bending test set up was created and tested by FE analysis on Abaqus and followed by lab testing as a part of validation.*

Keywords - *SMC, thickness, DOE, lab testing, automobile roof*

I. INTRODUCTION

SMC is highly advanced plastic composite material. It is strong, light weight and has better surface finish than fiber reinforced plastics (FRP) [1]. Hence, it has become more popular in manufacturing auto body panels. Lighter body results in increase in fuel economy and reduction in CO_2 emission. Automobile industry is familiar with SMC parts since 1987 as it was used to manufacture rear air deflector, tailgates, hoods and exterior panels [2]. Because of SMC's mechanical properties and light weight it can be used to build automobile roof which was previously made of sheet metals. Here while replacing; the new SMC roof can take all dimension or geometry of traditional sheet metal roof except its thickness. Existing metal roof used 0.8 mm thick sheet metal and fulfill FMVSS 216 [3] criteria which is a NHTSA's safety regulations for rollover accidents. For SMC materials, it is not possible to achieve 0.8 mm thickness due to manufacturing limitations and even though it is made, it cannot take enough load and impact like sheet metal. If higher thickness SMC sheets were chosen, it contributed additional weight to roof assembly which was not desirable. Hence, a proper thickness of SMC sheet must be selected which provides enough strength and contributes less weight as compared to sheet metals.

In this paper, a relation between material thickness and respective strength was presented. It was done by DOE technique of a bending test carried on a test specimen of 0.8 mm sheet metal of and SMC specimen of various thicknesses. As FEA testing method is fast, accurate and less expensive, it was used for DOE on above stated specimens. First a sheet metal specimen was tested and its deflection for a certain amount of load was recorded. This amount of deflection became a benchmark for suitable SMC specimen. Most appropriate thick SMC specimen was selected for laboratory test and results were compared. In laboratory test, both sheet metal and SMC specimen were loaded and the results were compared to validate the FEA results.

II. CHARACTERISTICS OF SMC

SMC composites show variety of mechanical properties with their percentage of glass content. They are basically Fiber Reinforced Plastics (FRP) but differ in manufacturing methods, glass filling and fiber orientations [4]. The fibers may be continuous (SMC-C) or randomly oriented (SMC-R). Sometimes the combination of both continuous and random orientation (SMC-C/R of XMC-3) can be used [4]. These products show wide range of mechanical and thermal properties. In this project, SMC-R was selected for test as it shows approximately equal strength in both lateral and transverse direction. The properties of SMC are described in Table 1.

Table -1: Properties of SMC

Sr. no	Property	Value
1	Tensile strength	160 MPa
2	Compressive strength	225 MPa

3	Poisson's ratio	0.27
4	Density	1.780 g/cc
5	Modulus of elasticity	11.7 GPa

SMC products are economical as compared with other plastic composites like aramid or carbon fiber [5]; it can be used in low commercial as well as passenger vehicles. It is approximately 4.5 times lighter than steel. Hence, it is popular in auto body exterior and interior parts. In rollover accidents, the roof is hit by ground and impact is transmitted to occupant. Since the base of SMC is polymer, it can absorb shock and impact energy. Another advantage of SMC for auto body exterior is that it has good surface finish and can be colored while it's manufacturing. Hence, no additional painting and surface treatments are needed.

III. FEA Set-Up

Material thickness is directly related to the overall weight of the roof. Hence, its selection must be carefully done with respective strength and deflection. When a component is loaded, it will deform with a certain amount depending upon the intensity of loading, material strength, component dimensions and the point of application of load. If the material is to be changed by keeping the load and loading conditions same, the component dimensions can be found out and that's how the thickness can be determined since it is a part of principal dimensions. In order to observe this phenomenon, a DOE technique using finite element analysis was used. A sample specimen of existing material was loaded as shown in fig.1 with the length taken as 1.5 m and width as 10% of length i.e. 150 mm [6]. The thickness selection was the main role behind this experiment; it was kept as 0.8 mm which was the thickness of existing roof. This sample treated as a sheet metal lying on XY plane and loaded along Z axis. The ends were fixed in such a way that it might look like a set up for cylindrical bending. This sample was tested by finite element method using Abaqus. A planar shell element was used to construct the model in Abaqus and followed by quad meshing. Steel properties like isotropic material having Young's modulus (E) 210 GPa and Poisson's ratio 0.3. Boundary conditions were applied by blocking respective DOF at both the ends. A pressure load was taken 1000 kN/m and it was applied along Z axis. The main aim of this experiment was to find the maximum deformation of steel plate for given load and thickness.

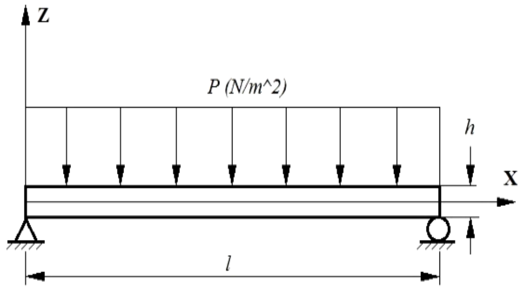

Figure 1. A typical bending test set- up

From the results obtained by Abaqus, it was observed that the maximum deformation was found at the middle of specimen and it was recorded as 6.588 mm for 0.8 mm thickness as shown in fig. 2. Along with this result, the platform was created for selecting a suitable thickness of SMC material for 6.588 mm deflection. Hence, in above FE test, the steel material was replaced by SMC with properties E = 11.7 GPa and Poisson's ratio 0.27. The material considered isotropic as SMC R was used [4]. Multiple tests were conducted on various thicknesses ranging from 1 mm to 10 mm and their respective maximum deformations were plotted in fig. 3. For same deformation as 6.588 mm, SMC showed its thickness value as slightly more than 2 mm.

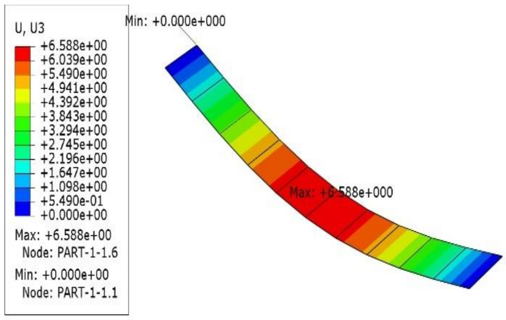

Figure 2. Displacement plot of sheet metal after bending test

It can be seen from above plot that the maximum deformation was drastically decreased as the thickness increased. It can be safer to select higher thickness SMC sheet but there was chances of weight increment of roof. Hence, the suitable thickness of SMC selected was 2.5 mm which gave the base value of maximum deformation of steel plate.

IV. EXPERIMENTAL

From FE analysis, it was seen that the 2.5 mm thick SMC plate may replace the 0.8 mm sheet metal. This result was validated by the experimental technique by 3-point bending test. In this case, uniform pressure load was replaced by a point load having line contact with specimen surface. Two specimens were used for experiments. One is 0.8 mm sheet metal and another was 2.5 mm SMC plate with same span length and width. The test was conducted on universal testing machine of load cell 980N as shown in fig. 4 and 5. The test set-up and loading conditions were stated in Table 2. The loading was kept quasi static as gradually applying load with speed 10 mm/min. The aim of this experiment was to determine deflection and load taken by both the specimens when same set-up and environment was provided.

First test was conducted on sheet metal which showed a pick load of 22.05 N with 10 mm displacement as shown in fig. 6. Its plot showed approximately linear characteristic at the beginning of loading and became non-linear after 18 N since sheet metal made from a ductile material i.e. steel. On the other hand, SMC showed a pick load of 39.3 N with 8.63 mm maximum deflection. At this point, breakage of SMC plate occurred. Fig 7 showed the load vs. displacement curve for SMC plate. The non-linear characteristic and a breakage indicated a typical plastic material. SMC plate gained its maximum load limit and break. Both these results were recorded in the computer attached with universal testing machine.

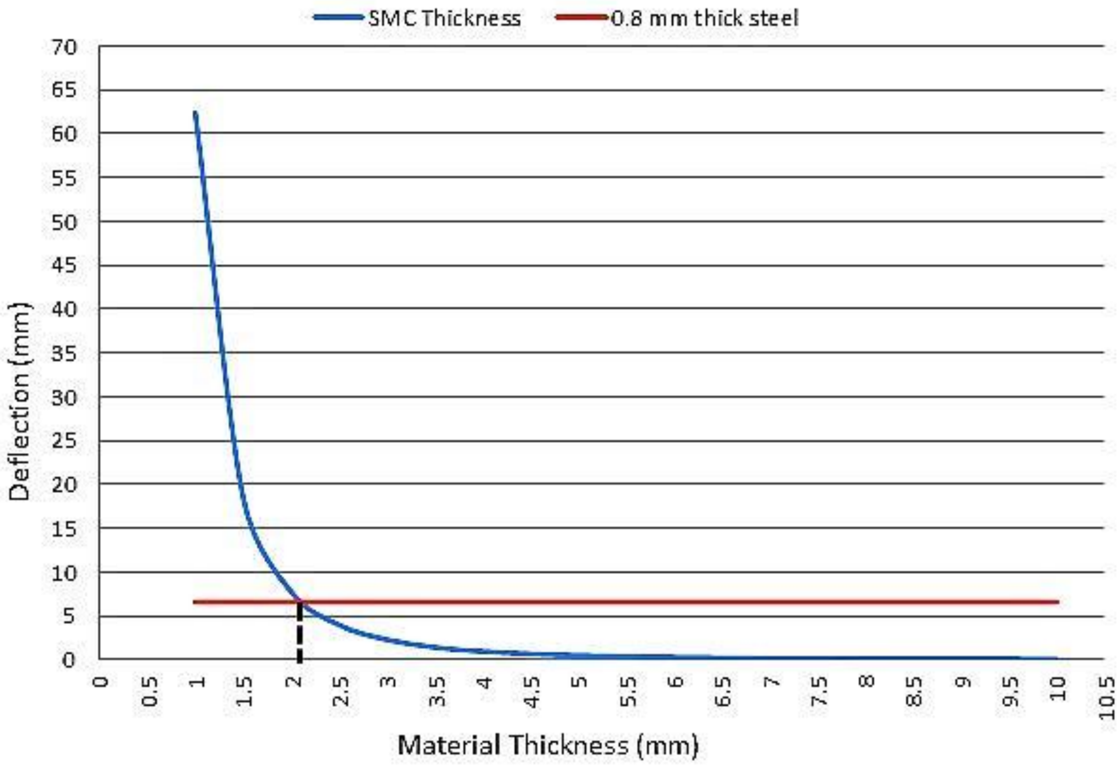

Figure 3. Material thicknesses Vs. Deflection plot for SMC sheets

Table -2: Experimental test set-up

Load cell	980N
Temperature	25^0C
Speed	10 mm/min
Pre tension load	0 N
Gauge length	50 mm
Specimen width (*b*)	25 mm
Span length (*l*)	65 mm

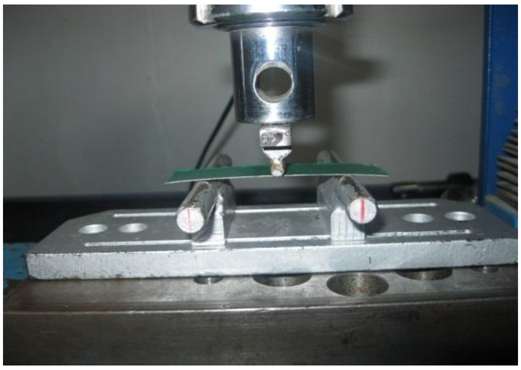

Figure 4. 3-point bending test set-up for sheet metal

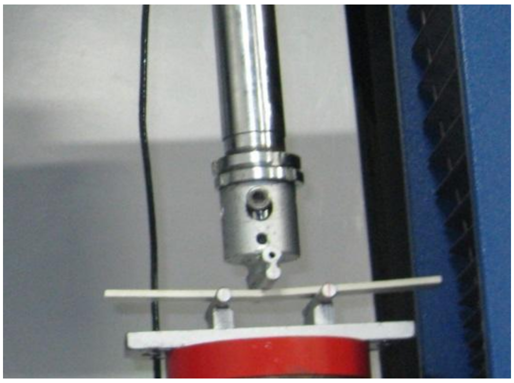

Figure 5. 3-point bending test set-up for SMC

Peak load observation-

Maximum load for sheet metal= 22.05 N
Maximum load for SMC plate= 39.3 N

Deformation observation-

Deformation at peak load,
For sheet metal= 10 mm
For SMC plate= 8.63

Weight calculation-

The weight of the specimens was calculated by,
W= volume x density
W= *b* x *l* x *t* x density

Weight of sheet metal = 2.5x6.5x0.08x7.85
= 10.205 gm.
Weight of sheet metal = 2.5x6.5x0.25x1.78
= 7.23125 gm.

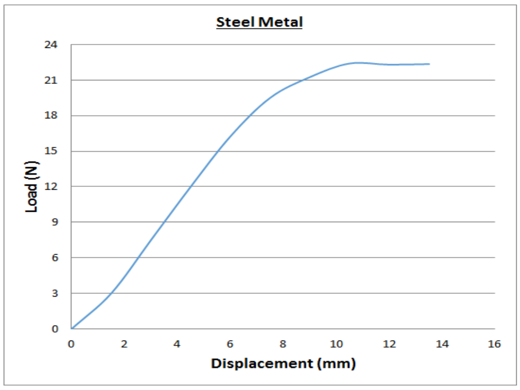

Figure 6. Load Vs. Displacement plot for sheet metal

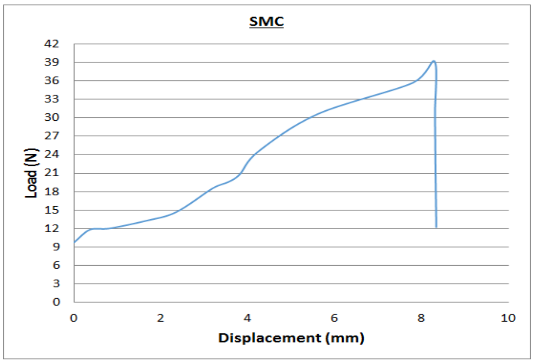

Figure 7. Load vs. Displacement plot for SMC

V. Result and Discussion

It was seen from tests and observations that the SMC with 2.5 mm thick sample showed higher load carrying capacity i.e. 39.3 N than that of sheet metal i.e. 22.05 N. It means SMC is having 78% more strength than sheet metal for that specimen. Also the deformation at the maximum load for SMC is less than sheet metal. SMC plate gave high load with 1.37 mm less deformation for that specimen.

As a matter of weight reduction, SMC plate is approximately 30% lighter than sheet metal specimen.

VI. Summary and Conclusion

In this work, the SMC material was studied and tested by both FE as well as experimental methods. The results were compared with sheet metals. Due to various advantages of SMC material, it can replace the traditional sheet metal body parts and this approach was elaborated. When SMC replaced the sheet metal for a specific application, an optimized thickness has to provide to it. This exact thickness was determined by FE analysis on bending test. The base deformation value of sheet metal was determined first i.e. 6.588 mm and for same deformation the SMC sample thickness was selected. This sample thickness was tested experimentally and results were compared with sheet metal result.

SMC material provided more strength and less deformation as well as lighter than sheet metal. It is non-corrosive, having high surface finish and can be molded in any shape and sizes. Hence, SMC can be an alternative material for sheet metal for automobile body panels.

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