INVESTIGATION ON FORMABILITY OF SANDWICH SHEET PANEL

SANTOKI KARAN\textsuperscript{a}, P MURALI NATH\textsuperscript{b}, Dr.ASHVIN MAKADIA\textsuperscript{c}

\textsuperscript{a} santokikaran9@gmail.com, \textsuperscript{b} muralininath@rku.ac.in, \textsuperscript{c} ashvin.makadia@darshan.ac.in

\textsuperscript{a} UG Scholar, \textsuperscript{b} Assistant Professor, \textsuperscript{c} Associate Professor

\textsuperscript{a,b,c} Department of Mechanical Engineering

\textsuperscript{a,b} R K UNIVERSITY, Kasturbadham, Bhavnagar Highway, Rajkot, Gujarat 360020

\textsuperscript{c} DARSHAN INSTITUTE OF ENGINEERING & TECHNOLOGY, Hadala, Morbi road, Rajkot.

Abstract

Due to globalization the necessity, comfort and the capital on the automotive parts is gradually paving its way in optimized development of the automotive parts. Sheet metal has a vital role in the field of automobile. The paper highlights about the process involved in the fabrication of the sandwich sheet metal, its importance in the usage based on reduction of weight, reducing energy. It is identified from the study that a core material like plastic, foam, glass fiber-reinforced polyester skin with foamed plastic core etc. can be used as a sandwich in between two metal sheet skins. Study on carbon fiber reinforced plastics for lightweight parts in sheet forming process has been done. Various formability evaluations and several tests were studied where the researches focused on in-plane stretching, out plane stretching, flexural testing. A suitable material for the work to be carried out based on the study done has proposed. A study on Nano particles has also been carried out to incorporate the development of the new sandwich sheet metal and also to carry out the analysis.

Keywords: Sandwich sheet, formability, light weight, out plane stretching.

1. INTRODUCTION

The environmental issues faced by the people in terms of transportation and other related issues had also paved the way for the development of the new sheet metal. Sandwich sheet metal is the new type of sheet metal where the sheet is integrated with two skin metal sheets and a core material which has different density, physical properties. From the research study done it was found that based on the mechanical properties of the metal Al type of material is most predominantly used in the field of automobile sector based on its properties. The hardness and the tensile properties of the aluminium skin related series shall be considered and the plastic core and foam shall also be considered in the experimental study and a conclusion shall be drawn based on the results as those of the sandwich sheet.

Among various laminates and sandwich sheets, aluminium/plastic/aluminum (Al/P/Al) sandwich sheets have generated a considerable interest from the automotive industries as potential lightweight materials for the body panels of the future high performance vehicles [1]. There are two
major trends in the forming of lightweight products with high strength [2], and the other is to stamp a hot sheet and then quench it to strengthen the stamped sheet [3]. Kim et al. [4] have developed a sandwich sheet from the materials like, Aluminum alloys and polypropylene (AA/PP/AA), by the roll bonding of two AA5182 Aluminum alloy skin sheets with a pre-rolled polypropylene core sheet at 1400°C, the strain-hardening exponent of the Aluminum skin was higher than that of the sandwich sheet, while the strain rate sensitivity of the sandwich sheet was higher than that of the Aluminum skin. In order to optimize the sandwich sheet, the formability has been analyzed by constructing the forming limit diagram (FLD). Reiner Kopp et al. [5] have proposed a unique optimization potential of sandwich sheets with respect to a defined criterion, example reduction in weight, which originates from the combination of different materials into one sheet. Due to this material combination, the sheet behaves differently from conventional sheet materials during forming and in addition unique failure modes like delamination might occur.

From the research study it is very clear that many of the researches had studied and carried out their experiments by using the plastic material as the core material in the sandwich sheet. My works aims in using the foam as the core material and also compare the results for both materials to precede the work in the formability and deep drawing of sandwich sheet metal.

**Deep drawing** is one of the most important sheet forming processes which is used in the automotive, home appliance and aerospace fields. The limits of this process are the onset of wrinkling, fracture failure and drawn-in failure. In order to meet great market demands for lighter, safer and cheaper formed products, it is necessary to select the proper drawing parameters which influence the drawing operation [6]. In deep drawing process one of the defects viz. wrinkling can occur in certain regions when it is subjected to compressive stresses. Fiber-metal laminates (FMLs) are new type of composite materials which could improve defects of traditional composites in ductility, formability, impact and damage tolerance. The experimental results indicated that the general effects of blank-holder force on the failure mode in FMLs and the effects of blank diameter and blank thickness of a FML in deep drawing was similar to custom metals. Furthermore, results concluded that wrinkling can be avoided by collaboration with the high temperature and blank force can be implemented [7].

Morovati et al. [8] studied the wrinkling of two-layer (aluminum-stainless steel) sheets in the deep drawing process through an analytical method, numerical simulation and experiments. The effects of several parameters on the deep drawing process of laminated metal sheets were studied by Atrian and Fereshteh-Saniee [9]. Their main aim was taking the advantages of different materials, such as high strength, low density and corrosion resistibility at the same time and in a single blank. Davey et al. [10] developed a finite element model to simulate the stamp forming of CF/PEEK sheets. This model was validated based on stamp forming experiments performed under various blank holder forces.
in which the evolution of strain was measured and compared to the results of finite element simulations.

**Finite Element Analysis**

Finite Element Analysis has got its importance and copious advantages. The concept of having the FEA is that the number of prototypes can be reduced, a new design can be proposed and may be modeled to determine its behavior and properties in the real world under various load environment. According to the research study done on the sandwich sheet metal material after performing the experimental values validation was done by many researchers on much available software like LS-Dyna, ABAQUS, Dyna etc.

Jianxun Zhang et.al [13] had carried out the finite element calculations to study the plastic behavior of fully clamped geometrical asymmetric sandwich beams with a metal foam core under transverse loading. ABAQUS software was employed in the calculations and four node and bilinear plane strain quadrilateral elements with full integration were selected to model both the foam core and the face sheets. A proper mesh refinement at the location of loading point and near the end support of the sandwich beam was included and mesh sensitivity was checked in calculations. The displacement loading was applied to a rigid circular roller. Contact between the outer surface of the top face sheet and the rigid roller is modeled through frictionless contact provided by the ABAQUS code.

Narayan Pokharel and Mahen Mahendran [15] had undertaken Australian sandwich sheet metal and had conducted experiments and FEA. Appropriate models were developed to simulate the foam supported steel plate and sandwich panels in building structures. The thinner the material ratio of b/t can be high Mahendran and Jeevaharan [14]. Results have shown inadequacy of using the conventional width approach. Conventional width approach was not found feasible in using Australian sandwich sheet hence a methodology was proposed.

2. **Sandwich sheet metal manufacturing & experimental work.**

Heinz Palkowski and Günther Lange [11] had proposed a methodology for the fabrication of the sandwich sheet metal. The sandwich sheet shall comprise of three layers of materials namely two metal sheets and a core material which is sandwiched between the two metal layers.

![Fig 1. Structure of a sandwich composite](image_url)

Methodology followed in their work was done with a cooling and a heating system under a press. Initially the two different sandwich sheet metals Al 5083 & Al 6061 were cleaned properly and the core material PU has taken and then an adhesive agent araldite was applied on either sides of the
sheet metal. Here the Facing material sheet thickness is 1mm (19 Gauge) and the core material sheet thickness is 3mm. This sheet metal was pressed in press machine. The capacity of this press machine is 60 KN force applied on sheet to make the composite sheet and the sandwich sheet metal is shown in below fig.

![Sandwich sheet metal](image1)

**Fig 2. Sandwich sheet metal**

**Table 1. Compositions of the aluminium material Al 5083 and Al 6061 which is used to make sandwich sheet metal.**

<table>
<thead>
<tr>
<th>Material Designation</th>
<th>Si%</th>
<th>Fe%</th>
<th>Cu%</th>
<th>Mn%</th>
<th>Mg%</th>
<th>Cr%</th>
<th>Al%</th>
<th>Zn%</th>
<th>Ti%</th>
</tr>
</thead>
<tbody>
<tr>
<td>5083</td>
<td>0.40</td>
<td>0.40</td>
<td>0.10</td>
<td>0.4/0.10</td>
<td>4.0/4.9</td>
<td>0.05/0.25</td>
<td>Rem</td>
<td>0.25</td>
<td>0.15</td>
</tr>
<tr>
<td>6061</td>
<td>0.4/0.8</td>
<td>0.7</td>
<td>0.15/0.4</td>
<td>0.15</td>
<td>0.8/1.2</td>
<td>0.04/0.35</td>
<td>Rem</td>
<td>0.25</td>
<td>0.15</td>
</tr>
</tbody>
</table>

This press machine is hydraulic press machine, in this cold pressing process was used to press this all sheet. This press machine give vertical force on the sheet and make it composite sheet. This composite sheet metal gives more bending strength and flexural rigidity.

![Press machine](image2)

**Fig 3. Press machine**

The other proposed by Heinz Palkowski and Günther Lange [11] is fabrication of the sheet metal by using rolling methodology, the sheet metal of two each 0.5 mm were considered and a polypropylene foil of same thickness was considered in his work. Two sheet metals were degreased and an adhesive agent was coated on either sides of the sheet metal. After the addition of the adhesive agent the sheets are placed one above the other. In the next step the three sheets after being placed one above the other and were rolled under the rollers. For a proper bonding a certain temperature was considered with time duration as shown in figure 4.
Fig 4. Fabrication process of a sandwich panel

Table 2. Properties Al 5083, Al 6061 and the PU foam

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Properties</th>
<th>Al 5083</th>
<th>PU</th>
<th>Al 6061</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Density</td>
<td>2.65 g/cm³</td>
<td>0.062 g/cm³</td>
<td>2.7 g/cm³</td>
</tr>
<tr>
<td>2</td>
<td>Modulus of Elasticity</td>
<td>72 GPa</td>
<td>69 GPa</td>
<td>68.9 GPa</td>
</tr>
<tr>
<td>3</td>
<td>Poisson’s ratio</td>
<td>0.33</td>
<td>0.32</td>
<td>0.33</td>
</tr>
<tr>
<td>4</td>
<td>Tensile Yield</td>
<td>218 MPa</td>
<td>138 MPa</td>
<td>276 MPa</td>
</tr>
<tr>
<td>5</td>
<td>Ultimate Tensile Stress</td>
<td>317 MPa</td>
<td>40 MPa</td>
<td>310 MPa</td>
</tr>
<tr>
<td>6</td>
<td>Thermal Conductivity</td>
<td>121 W/mk</td>
<td>0.209 W/m²°C</td>
<td>167 W/mk</td>
</tr>
<tr>
<td>7</td>
<td>Tensile Strength</td>
<td>275-350 MPa</td>
<td>69 MPa</td>
<td>207 MPa</td>
</tr>
<tr>
<td>8</td>
<td>Thermal Expansion</td>
<td>25E-6 °K</td>
<td>100E-6 °C</td>
<td>23E-6 °K</td>
</tr>
<tr>
<td>9</td>
<td>Brinell Hardness</td>
<td>75 HB</td>
<td>90 HB</td>
<td>95 HB</td>
</tr>
</tbody>
</table>

From this composite material I have cut the sheet metal in different angle to check its anisotropy. To check it I have cut the sheet metal into the horizontal, vertical and on 45° angle and conduct different tests on it like tensile test, 3-point Bending test and Ericshen cupping test. For accurate result on each part conducted same test 3 times on it.

In this tensile test process the material is held in to jaws upper and bottom as shown in below fig 5. During this test the material is stretched and deformed in its size, the length of the material will increase and the cross section will be decrease. This testing process is continue till the material is not break or not get any type of fracture. During this process it found the strength of the material and it is measured in terms of stress. This thing is help to find out whether this material is useful for further work or not. It also gives the ductility properties of the material which shows its deformation ability. This property is very important criteria for the engineering design. If the material ductility property is less its deformation capability also less and it has low resistance.

Fig 5. Setup of tensile test for sandwich sheet.

In this tensile test machine the specimen are cut in different angle from the main composite sheet for checking the anisotropy of the material. Here the size of the
specimen is 75 × 300 mm. After the tensile test of the specimen it look like given below.

![Specimen after tensile test carried out](image)

*Fig 6. Specimen after tensile test carried out.*

Bending test gives the idea about flexural strength, it is also known as modulus of rupture, bend strength or fracture strength is a material property, defined as the stress in a material just before it yields in a flexure test.

The bending test is the common test which is mostly done in many industries on the different types of sheet metal and sandwich sheet metal too. The transverse test is also commonly carried on the sheet metal. The force is applied on the sandwich sheet metal, during that time cross section is bent until the fracture occurs or up to the yield point this is called 3 point flexural test technique. This gives the highest strength result of the material and it is measured in terms of stress.

![Bending test apparatus set up](image)

*Fig 7. Bending test apparatus set up*

The sandwich sheet gives the higher flexural rigidity. After the 3 point bending test the specimen it look like given below as shown in the fig.

![Bending test apparatus set up](image)

*Fig 8. Specimen after performing flexural test*

In older setup of the Erichsen Cupping test, there were no control or arrangement of the clamping force. The sandwich sheet metal is clamped in between retaining ring and die than it press the sandwich sheet metal by spherical ball until the fracture found. In this sandwich sheet when spherical ball is penetrate the depth is found on it, this measured of depth is called Erichsen index.

Practical ERICHSEN CUPPING TEST equipment have been repeated for different material specimens of different thickness using different lubricants like castor oil, lanthax grease and general multi-purpose grease are found. From the practical experiment it observed that Erichsen index will increase with increase in the thickness of the sheet metal.
Fig 9. Erichsen Cupping Test Machine

Here the sphere is used in this experiment its diameter is 20 mm. The arrangement of this setup is as shown in fig. The hand wheel is given in this machine, it rotate and the sphere moves towards the Sandwich sheet metal. This sphere is penetrate into the sandwich sheet metal and get the depth as shown in figure.

In this Erichsen Cupping Test the crack found after the sphere is penetrate up to the depth around 8 to 9 mm. Here the sandwich sheet metal is cut in the different angle from the main sheet and check the result of it

Fig 10. Specimen after Erichsen Cupping Test

3. Results & discussion.

In the below table 3 display the readings of the result of tensile strength of the sandwich sheet specimen which are cut at different positions from the main sandwich sheet panel by using ASTM E8 as standard. These practical tests are conducted on the sandwich sheet metal at the different position pieces that are cut from the main panel like horizontal, vertical and 45°. It gives the results around 77 MPa.

<table>
<thead>
<tr>
<th>SR NO.</th>
<th>Tensile Test Specimen</th>
<th>Result (Force) (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Average Horizontal</td>
<td>74.49</td>
</tr>
<tr>
<td>2.</td>
<td>Average Vertical</td>
<td>77.68</td>
</tr>
<tr>
<td>3.</td>
<td>Average 45°</td>
<td>75.52</td>
</tr>
</tbody>
</table>

Above fig 11 shows the meshing structure of the sandwich sheet metal. The sandwich sheet metal is placed on the die and the punch is on the top of the sandwich sheet metal. The punch applied force on it and the sandwich sheet metal get bend as shown in fig 12

Graph 1 Tensile Test Result
The graph 1 shows the variation of tensile test on the sandwich sheet metal. This result is better than the other metals results.

Fig 11. Meshing structure of sandwich sheet metal

Fig 12. Analysis of sandwich sheet metal during Bending

Above fig 12 shows the bending of the sandwich sheet metal and it dives the result as flexural stress or flexural stiffness is around 151.1 MPa and the deflection of the sheet is 0.5715m Max.

In the below table 4 displays practical readings for Erichsen Cupping test performed on the sandwich sheet metal. These practical tests are conducted on the sandwich sheet metal at the different angle like horizontal, vertical and 45°. It gives the results around 8.75 mm.

<table>
<thead>
<tr>
<th>SR NO.</th>
<th>Erichsen Cupping Test specimen</th>
<th>Result (Depth) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Average Horizontal</td>
<td>8.73</td>
</tr>
<tr>
<td>2.</td>
<td>Average Vertical</td>
<td>8.8</td>
</tr>
<tr>
<td>3.</td>
<td>Average 45°</td>
<td>8.76</td>
</tr>
</tbody>
</table>

The graph 2 shows the variation of Erichsen Cupping test on the sandwich sheet metal. This result is better than the other metals results.

4. CONCLUSION

From the research study done a sheet metal of Aluminum alloy shall be considered and both the theoretical and empirical part shall be carried out in order to carry out the work in the formability and deep drawing of sandwich sheet metal. Based on the study
done aluminium metal is considered to be the suitable for the fabrication of the sandwich sheet panel. Aluminium its alloy have been selected for the experimental work. Here Al 6061 – T6 and Al 5083 – H111 are used and for the core material polyurethane is used. After the sandwich sheet metal has been formed different tests are conducted like Tensile Test, 3 point Bending Test and Erichsen Cupping Test on it to check its strength, flexural rigidity etc. The necessary standards were followed to conduct the test by performing the tensile test on the sandwich sheet metal panel it did not had any impact such that there was no deformation in the specimen, instead the material was separated into three individual layers with a small tearing in the panel according to the position of the dies arranged. Here when practically conducted the Bending Test on the sandwich sheet panel had been deformed its shape by applying 80 to 90 KN force on it and to validate the test analysis is been done on ANSYS software and around same result is been found and the flexural rigidity is around 151 MPa after analysis in ANSYS software. During Erichsen Cupping Test the Sphere impact on the sandwich sheet metal is also give better result than any other metal, in sandwich sheet metal the crack is found around 8 to 9 mm depth in it.

References

[15] Narayan Pokharel and Mahen Mahendran. Finite Element Analysis and Design of Sandwich Panels Subject to Local Buckling Effect. Sixteenth International Specialty Conference on Cold-Formed Steel