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Design and Implementation of Different Truss Core Laser Welded SS304 Grade stainless Steel Corrugated Core Sandwich Panel's Optimum Response to Dynamic Force

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Abstract:

Sandwich panels made of corrugated core steel are a practical solution to lighten and stiffen steel structures. These panels have demonstrated very promising economic potential in a variety of applications such as automobile, marine and aircraft. The laser welded panel with different geometric parameter offers the high strength to weight ratio. The laser welding is used because it has excellent economic and operational efficacy, as well as its low weight and high strength to weight ratio. The weld width, weld misalignment, and a plate gap between the face sheets and cores are the geometric characteristics of the connection .The corrugated core sandwich panels with dual weld lines per crest are used generally. This study describes the process of designing, manufacturing, and commercialising corrugated core sandwich panels. The typical low-carbon steel grade SS304 and ferritic stainless steel grade SS305 with the plate thicknesses of 2mm, 4mm, and 6mm are utilised as test materials for corrugated cores and skin plates. This study describes the process of designing, manufacturing, and commercialising corrugated core sandwich panels. The result's findings shows that the induced stress and corresponding deformation of both top and bottom face sheets with core is proportional to varying compressive loads and height of the core . As the core height varies, strange changes in both impact accelerations and degrees of deformation occur. The current work is Investigating and analysing the effects of geometric factors for a particular increasing load operating on the surface of the panel and comparing the experimental results with FEA and analytical result for different geometric configuration, as the results shows that the experimental, numerical ,and analytical findings are consistent.

Key words: Optimum Static, Dynamic Response, Laser Welded Corrugated , Core Sandwich Panel , Grade Steel Materials, Size effect ,Bending response Homogenization method,.

1.0 Introduction

In the modern world, sandwich-type composite construction is more and more common. This study focuses on a specific sort of sandwich construction in which a corrugated metal sheet is attached to two metal sheets at its crests and troughs. This structure is favourable in that the corrugated core isolates the faces, allowing for the achievement of a high second area moment and flexural stiffness. Since conventional welding cannot be done owing to a lack of access, the primary goal of sandwich construction is to build a core that is sufficiently stiff , so one face can execute sandwich construction. Spot fusion welding, however, can be a good substitute. For many years, many sandwich structure types have been employed in the sector. Sandwich panels are used to strengthen the construction's stiffness and durability while also decreasing the structure's weight and absorbing energy from crashes and explosions [1], [2] and [3]. According to Marsico, laser-welded steel sandwich panels can reduce the weight of conventional steel constructions by 30 to 50% [4]. Sandwich panels are lightweight and rigid due to their three-layer (skin, core, and skin) construction, which on the other hand increases the wall thicknesses of the structure. A core absorbs the shear loads and establishes a space between the skins, which absorb the in-plane compression and tension stresses that prevent bending [5]. The relative tensile and compressive moduli affect the bending deflection of the skin materials and shear deflection is depends on the shear modulus of the core [6]. There are several various core profiles, including honeycomb, I, O, V,

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and Z calotte , they could be individual ribbons or corrugated sheets for these profiles. For a sandwich structure to function optimally under loads, the orientation of the core ribbons must be carefully considered. When ribbons are transversely orientated the greatest bending resistance is obtained [7].

The core material should ideally be far thicker than the considerably stiffer and stronger face layer. Therefore, such grades are excellent alternatives to be employed in sandwich solutions due to the advantageous features of ultra high strength steel (UHSS). Typically, to model the production processes and forecast the final product's attributes, cost- and time-effective virtual methods are employed, such as the finite element approach. However, due to factors like the usage of mixed materials and delaminating among others, the application of sandwich systems presents additional modelling issues. For the sandwich concept to be appealing, numerical aspects relating to the complicated geometries producing an excessive number of finite elements, necessitating extensive calculation times, for correct discretization during component construction, must be taken into account. In the literature, a huge range of core materials have been provided, Corrugated sheets, foam, and honeycomb are typical cores [8]. Many researchers investigated honeycomb cores and found that they exhibited excellent lightweight qualities [9-11]. There are also other potential forms of laminated constructions, such as those made of fibre reinforced polymers or metal-based structures, like the aluminium laminate tested under three-point bending [12-15]. The corrugated cores of sandwich panels have been researched by several writers, .The corrugated cores of sandwich panels have been researched by several writers In order to allow for the decoupling of bending and stretching, they proposed a numerical representation of a homogenised and comparable core material [16]. The process used to determine the ABD-components matrix typically differs [17]. The ABD-matrix may be determined numerically, and there is good agreement between the data from the literature and the suggested method [18]. In order to calculate the ABD-matrix numerically, a representative volume element (RVE) is commonly investigated. In order to determine the constants in the matrix, the RVE is exposed to specific loading conditions [19]. It was done using traditional homogeneous boundary conditions (HBC). For orthotropic RVEs, these boundary conditions frequently overestimate or underestimate stiffness [20], because periodicity is not obtained. Periodic boundary conditions (PBCs) are suggested as an alternative. In order to reduce the costs and lead times associated with product development, efficient production techniques are required for sandwich panels with corrugated cores to be attractive to the industry [21], However, the material itself and the production method are more expensive and time-consuming. Furthermore, although this is not the case for components made of steel, it is more challenging to create such components continuously [22-25]. Fibre reinforced composite materials outperform steel in several ways, including high strength-to-weight ratio, resistance to corrosion, and design flexibility. The sandwich panels taken into consideration for this research are depicted in Figure 1, were built by bending the core sheets, and followed by full-penetration fusion welding using a laser welding with face sheets. Due to the restricted access required for conventional welding in this type of sandwich structure, laser welding is preferred. The Spot fusion welding, however, might be a good substitute [26-28]. Typically, a core is formed using mechanical rolling or pressing tools. A press brake can create one or more wavelike patterns in a single hit, while a profile roller creates a core between two tooth-gear-like rollers (figure 1a) (figure. 1b). Figure 1(b) shows a spring-loaded press keeping the sheet in place while being formed is part of the upper forming tool. Figure 1(b) demonstrates that the lower forming tool is made up of a number of machined and ground plates that are secured by screws [29]. Laser welding of skins to a core properly depends on a good core. In overlap joints, the air gap between weldable surfaces should be less than 0.2mm [8]. As a result, numerous clamps had to be added and removed while laser welding a panel that was 1.2 metres wide. Weld quality was generally good, but occasionally, only one seam could be welded at a time, which slowed down the operation [30]..

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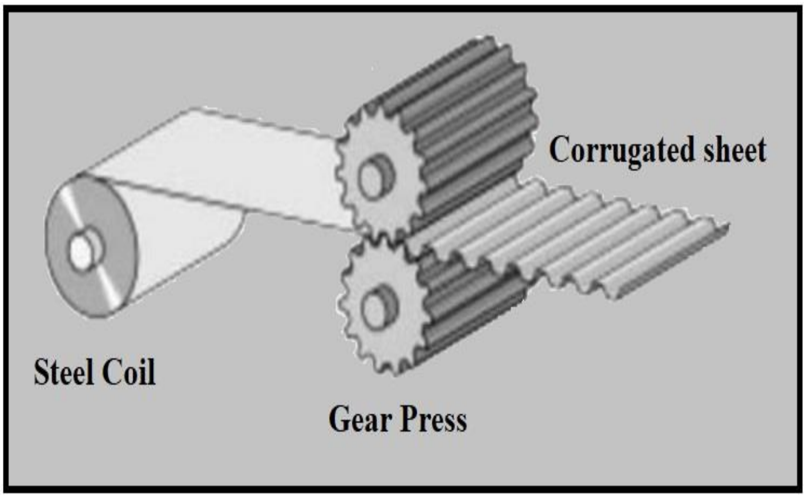

Figure 1(a) Mechanical Rolling Pressing tool

Figure. 1(b) *Press tool for making core,*

This research examines two industrial laser welding corrugated core applications where the outlines have been included into the finished goods.

2.0 Experimentation

The sandwich panel under examination has a corrugated core constructed of SS304 stainless steel and two stiff facing plates of equal thickness. The corrugated core's web is maintained at a constant 60-degree inclined. The same material is used to make both the face sheets and the corrugated core webs. The manufactured panel is put through a universal testing machine's progressive load test and comparisons between the experimental, theoretical, and FEA data were made. The material selection and detailed comperiemntal analysis is represented as follows

2.1 Material Selection for Corrugated Core sandwich panel for progressive load testing

Structural Steel is the material used in the sandwich panel. The specification, Modulus of Elasticity and yield stress are listed in table 1.

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Table 1 : Properties & Geometric Parameters of Sandwich Panel

SL NO	Description	Dimensions in mm
1	Length of the panel(L)	400
2	Width of the panel(b	200
3	Corrugation angle (ɵ)	60°
4	Material of the panel	Structural steel (SS304)
5	Density Of Material (ρ) ton/mm^3	ton/mm^3
6	Young's Modulus E	210×10^3 MPa
7	Poisson's ratio	0.3
8	Yield Strength(σ_y)	240 MPa
9	Shear Modulus (G)	80×10^3 Mpa

Standard stainless steel is grade SS304, which is also the most functional and popular stainless steel, available in a wider range of products, forms and finishes than any other. It has outstanding shaping and welding characteristics

2.2 Fabrication Technique Of Corrugated Core Sandwich Panel

A core and two face sheets make up the three primary components of a single layer sandwich. A corrugated sheet is sandwiched between two thin surface sheets to form a corrugated core sandwich structure. High strength to weight ratio is this structure's most significant characteristics of a corrugated core sandwich panel. The technique to form the corrugated core structure is mainly consist of

1) Forming the core
2) Laser welding of core and skins
3) Cutting of the panels
4) Joining sandwich panels together
5) Surface treatments

The detailed description of above said process is described as follows.

2.2.1 Forming of the core

All of the cores for the initial prototype were made from 2 mm-thick. The conventional and standard structural steel grade SS304 sheet made using longitudinal laminating technique and bottom-strike shaping tools as shown in figure 2(a) and able to form a 400mm-wide blank sheet. Dimensions of a corrugated panel are shown in figure 2(b) . The Ursviken Optima 100 is the press brake used in the forming process,figure1(b).

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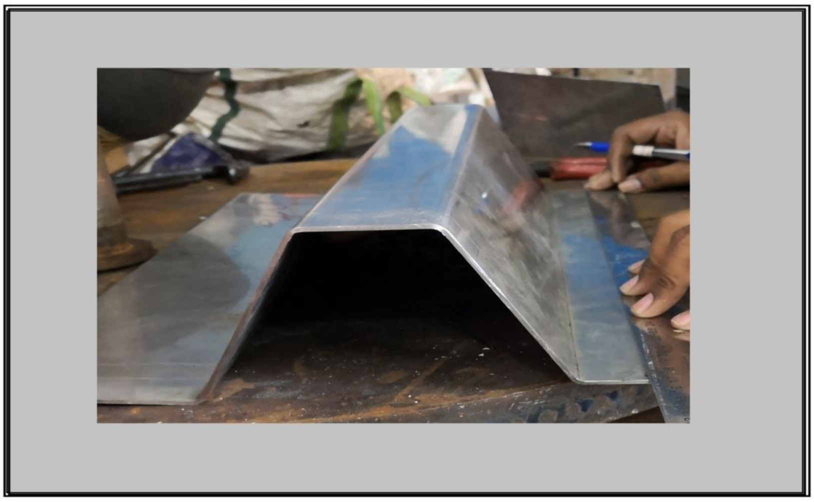

Figure 2(a) *. Corrugated core made by Press Tool*

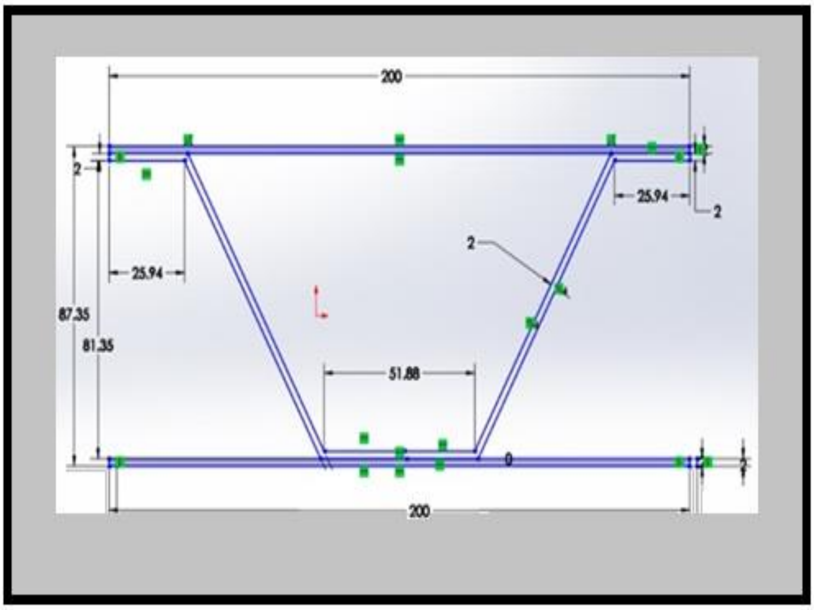

Figure 2(b*) . Dimensions of a corrugated core*

Weld seam quality is influenced by the quality of the core. Basically, at the welding line, there shouldn't be any air between a core peek and skin. A few tenths of a millimetre gap might affect the welding process and make a seam weld loose. A core profile's uniformity, such as its equal height, incremental distances, and parallelism of peaks, is crucial to the automation of the process.

2.2.2 Laser welding of the core and skins

A very practical method of attaching skins to a core is laser welding. The 4 kW diode pumped disc-laser was used to weld skins that were 2 mm thick and made of the same material as the core on both sides of the core. (Trumpf 4002) using 300mm optics and a focal point on the skin's upper surface (spot size 0.3 mm). This type of laser beam has an 8 mm beam diameter. The most significant challenge The biggest challenge is figuring out how to appropriately touch the highest points of the core and skin. Clamps were frequently inserted and removed throughout the labor-intensive welding procedure of a prototyping phase. At most, only two seams could be welded at once, with a maximum of six.

The quality of the welds was good at 180 mm/min welding speed and 2,3kW laser power. The limiting factor for higher welding powers and speeds was the acceleration of a six axis robot arm moving the laser welding head. Too much energy will be impacted on the welding spot if the entire laser power is turned on during the acceleration phase. One option was to accelerate the arm outside of the welding area and activate the laser beam once the arm arrived at the welding site. The prototype was made primarily of structural steel SS304 with correct welding as figure 3 shows

***Figure** 3. Laser Welding Of Corrugated core*.

The panels were made from 2mm thick stainless steel sheets grade SS304 for the second prototype cover cores as well as skins. More defects were discovered than with low-carbon steel panels, most likely as a result of the increased distortion of the welds brought on by the thinner stainless grade skin plates. The same laser, optics, and welding parameters used for the flat panels in Case 1 were used to laser weld rotationally symmetrical panels. Due of the rib tip's narrowness, which allows less room for tolerance for the lap weld, the laser beam location needs to be precise. The structure's lap welds may be welded effectively and with little heat input. Particularly while welding the outer skin, the skins and the core should be fully in touch at the welding spot. Because it is visible and therefore has an impact on the final product's appearance and quality.

Correct jigs and pressing tools are crucial for automating the welding process. An airtight contact between the core peaks and a skin in the full area of the chuck was discovered to be provided by a magnetic chuck with a holding force of 100 kg in preliminary testing. – However, a magnet may only be helpful when joining the initial skin, as seen in figure 4. Due of the magnetic force's rapid deterioration, chunk is worthless for the second skin when the distance increases.

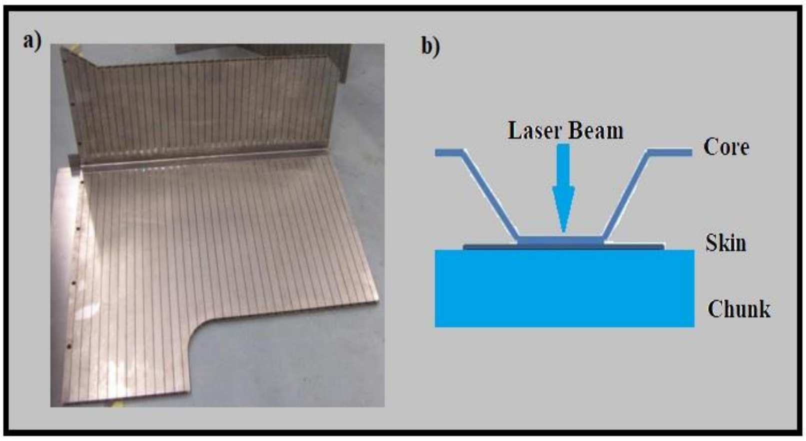

***Figure 4** Welding of Skin with core*

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2.2.3 Cutting of the panels

An abrasive water jet cutter was used for shaping panels. The quality of the edges and holes is good. The disadvantage is that some sand will be easily left inside the panels and is quite time consuming to remove. Water jet cutting is also quite time consuming and thus an expensive method. Alternative cutting methods could be considered and tested like fine tooth circular sawing. A band sawing machine was also tested and found to be suitable for cutting panels.

2.2.4. Joining sandwich panels together

Corner brackets are welded as illustrated in the figure.3, the 2 mm-thick corner brackets were laser welded to each side of a corner at a welding speed of 100 mm per minute and a laser power of 3 kW. An experiment revealed how rigid the corner joint is, and later, brackets were made from thinner sheets. A bracket is required to weld just on the opposite side of a corner since panels were also successfully bent between two peaks of a core. Bending could only be used between two peaks in a core. In order to avoid air gaps and part slippage during this assembly step, suitable jigs and clamps should be created and employed.

2.2.5 Surface treatments

It is important to take into account how easily thin carbon steel sheet metal panels will corrode and whether or not edge lists should be inserted into the panels. Edge lists were Laser-welded to the prototype cover for the purposes of the prototype, but there is really no reason why laser welding couldn't be employed as well. Snap-on solutions some sort of might be considered. Galvanizing panels, i.e. before installing an edge list, could be an option if better corrosion protection is required.

3.0 Geometry and modelling of corrugated core sandwich panel

Two face sheets of equal thickness and a corrugated core make up the sandwich panel under examination. The sandwich panels are modelled in Solid Works. The corrugated core is modelled using the sweep command, the top and bottom plates are modelled using the extrude command, and all three of these elements are combined using the assembly command .The modelled sandwich panel is shown in figure 5. In the following step, completed parts are stored in IGS format and imported into ANSYS workbench. Long computational times are caused by the complicated geometries of the cores, which necessitate a high number of finite elements for precise description.

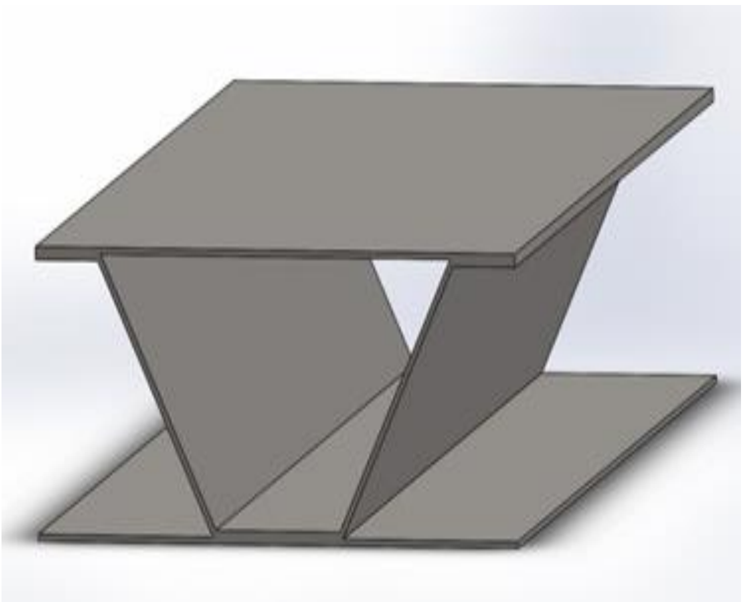

Figure 5. *Geometry of Corrugated core sandwich panel*

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4.0 FE-analysis of different frame structures for Progressive load analysis

In finite element analysis actual item is divided into a huge number (hundreds to thousands) of finite elements, such as tiny cubes, triangular and tetrahedral elements, etc, to simulate its behaviour. The use of mathematical formulas will aid in predicting how actual objects will behave. The finite element analysis method aids in predicting how a model will behave when subjected to a variety of physical factors, including mechanical stress, mechanical vibrations, Fatigue etc. The finite element analysis of given panel includes,

1. Geometry and material selection
2. meshing
3. Property Loading
4. giving the boundary condition
5. Adjusting the Parameter

The deflection and corresponding von mises stresses of the panel for different loading conditions by considering the geometric parameters constant for the cases 1 to 4 as

p = 100mm f = 51.88mm hc =83.35mm tc = 2mm tf = 2mm

Case 1: Total Deformation and von-mises stress for a load 15kN or 1529kg as shown in figure 6(a) and figure 6(b).

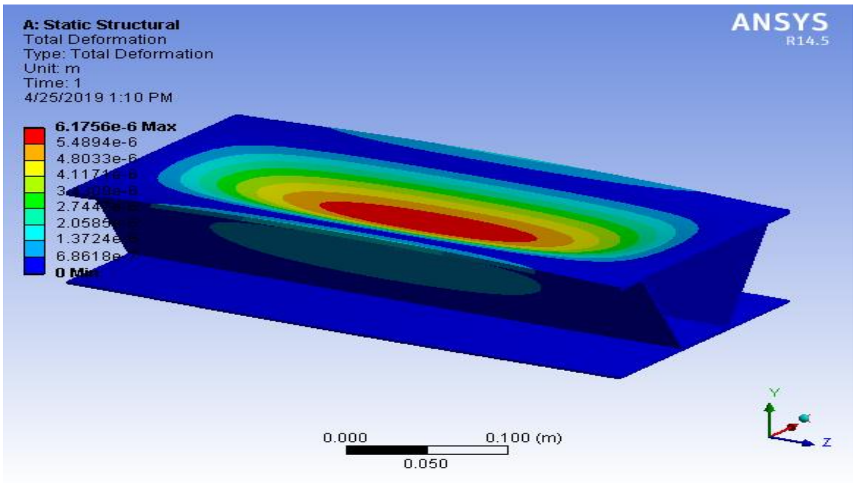

Figure 6(a) *Case-1 Total Deformation for case 1*

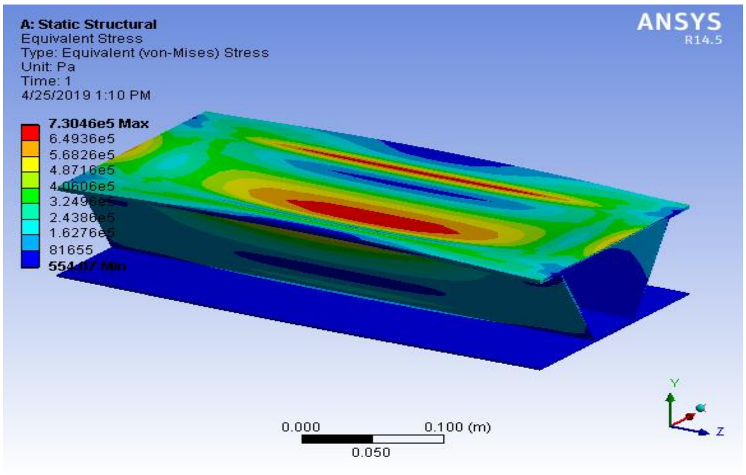

Figure 6(b). *Case-1 Von-Mises stress for case 1*

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Case 2: Total deformation and von-mises stress for a load 22kN or 2243.38kg as shown in figure 7(a) and figure 7(b)

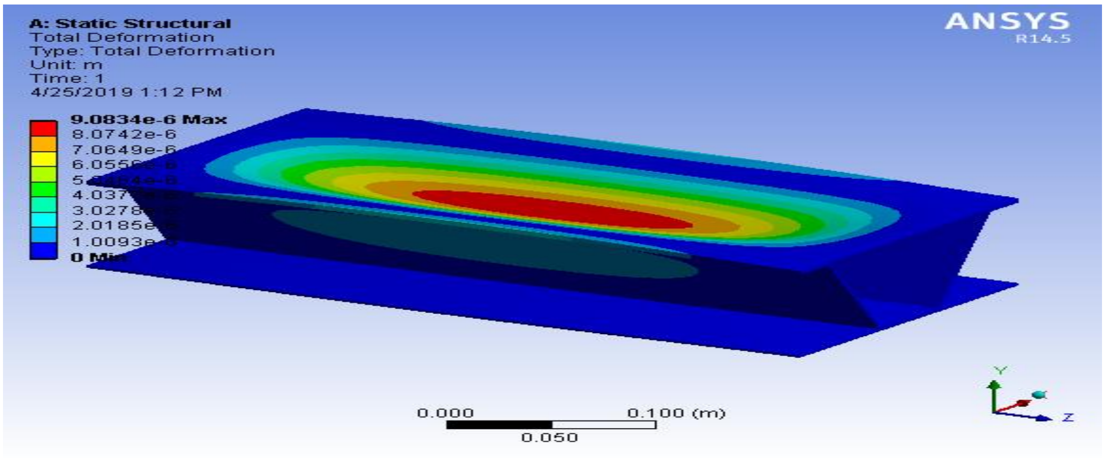

Figure 7(a). *Total deformation for case 2*

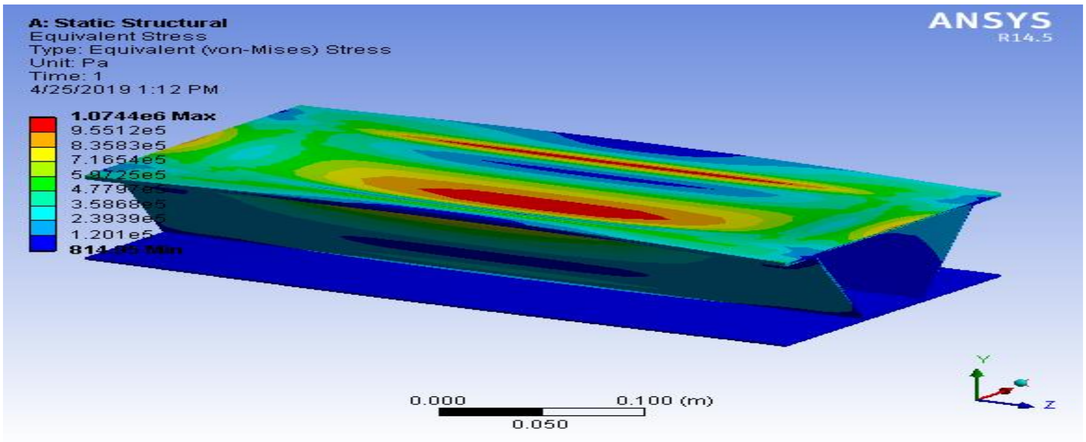

Figure 7(b). *Von-Mises stress for case 2*

Case 3: Total deformation and von-mises stress for a load 53kN or 5404.49kg as shown in figure 8(a) and figure 8(b)

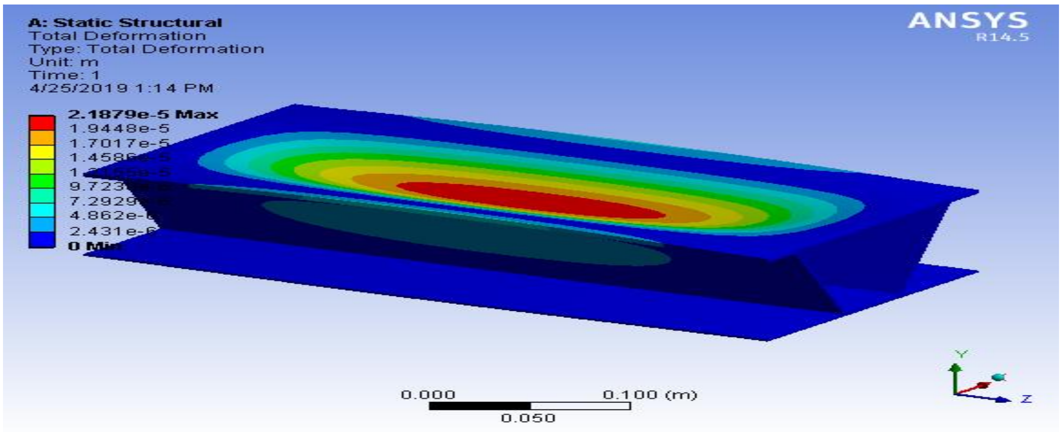

Figure 8(a). *Total deformation for case 3*

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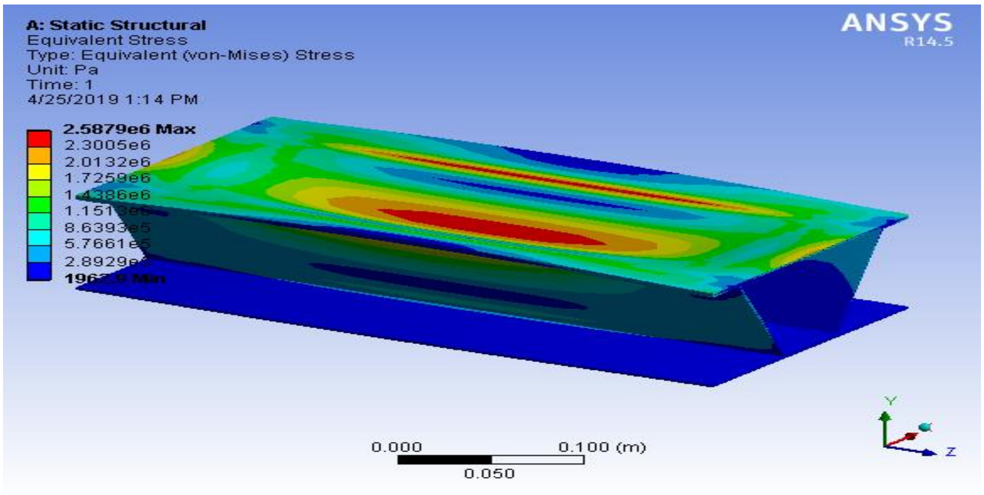

Figure 8(b). *Von-Mises stress for case 3*

Case 4: Total deformation and von-mises stress for a Load Applied 65kN or 6628.15kg as shown in figure 9(a) and figure 9(b)

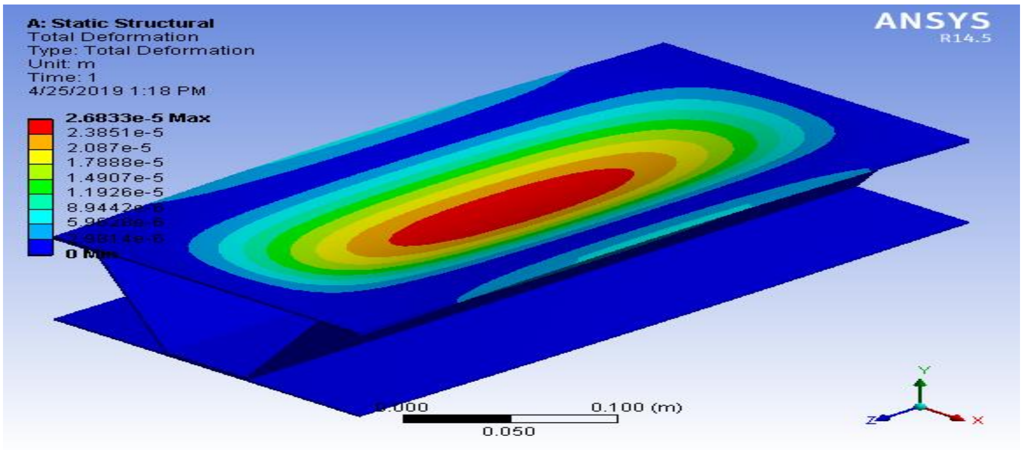

Figure 9(a). *Total deformation for case 4*

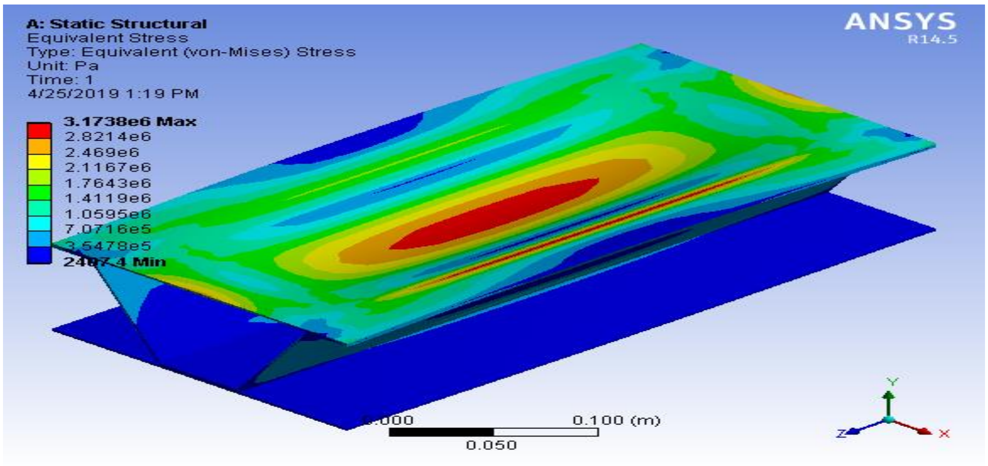

Figure. 9(b). *Von-Mises stress for case 4*

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5.0 Results & Discussion

In this research work the geometric configurations of a corrugated core sandwich panel is kept constant for all the increasing loads on a panel which are as shown in table 2 , the geometric parameters are p =100mm ,f = 51.88mm hc =83.35mm tc = 2mm tf = 2mm

Table 2 shows the comparison of the finite element results with theoretical and experimental data for a wide range of loads. The geometric properties of a sandwich panel with a corrugated core were preserved at their original levels throughout the experiment with shifting loads.

Table 2. Comparison of Finite element result with theoretical and numerical result

SL. No	Load		Height of the Panel in mm	Numerical deflection(δ) Mm	Theoretical deflection Mm	Experimental deflection
	Kg	**N**				
1	1529	15×10^3	87.3441	6.1756×10^{-6}	5.9874×10^{-6}	5.0122×10^{-6}
2	2243.38	22×10^3	87.3441	9.0834×10^{-6}	8.7221×10^{-6}	8.1004×10^{-6}
3	5404.49	53×10^3	87.3441	2.1879×10^{-5}	2.1054×10^{-5}	1.9871×10^{-5}
4	6628.15	65×10^3	87.3441	2.6833×10^{-5}	2.5876×10^{-5}	1.8741×10^{-5}

From the above table it is observed that as the load on a panel increases, then deflection of a panel increases.

Behaviour of a panel for different increasing loads

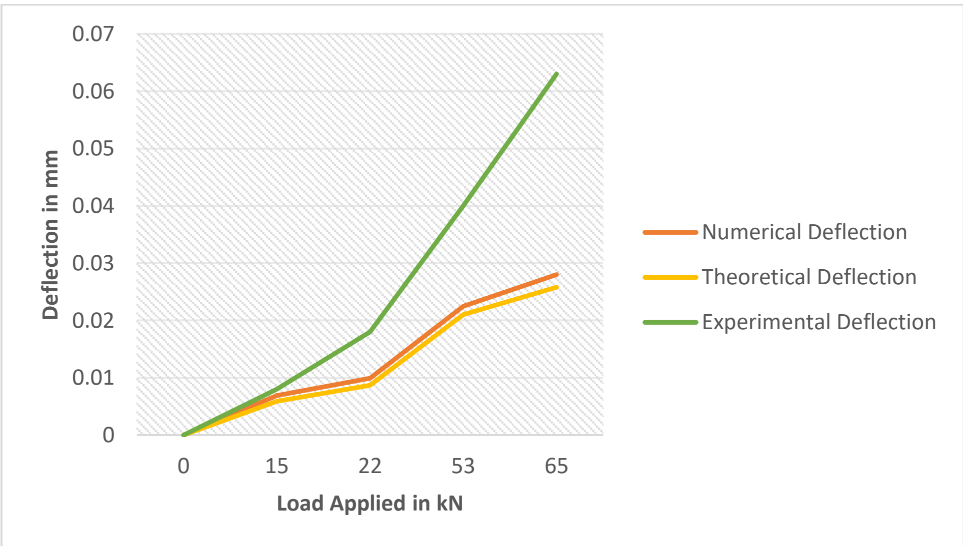

***Figure 10**: Comparison Of Numerical, Theoretical and experimental results*

Conclusion

- The static and dynamic analysis of sandwich panels with homogenised cores, the theory of laminated plates is used to calculate the ratio of span dimensions to plate thickness.
- The main aim of this current study is to investigate and analyse the impact of geometric parameters for given increasing load acting on the surface of panel.
- The Alteration in size of the face sheets and core, this paper's secondary goal is to explore the bending and dynamic responses of corrugated core sandwich panels. The homogenised cores are then numerically investigated by incorporating corrugated cores.
- The computed results show how variations in the thickness of the core plate and face sheets affect the dynamic bending and reaction of sandwich panels. The use of mathematical models is developed to evaluate and compare the results of experimental data with the numerical data.
- Despite how quickly laser welding works, welding arrangements took the longest. Low-carbon steels were shown to have less welding defects. (cores formed from 2mm thick sheets, skins 2mm thick sheets) compared to SS304, a ferritic stainless steel grade (skins and cores from 2 mm thick sheets) Probably because thinner skins deform stainless grade more severely and have higher distortion.

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