ANALYSIS OF AUXETIC STRUCTURES USING FINITE ELEMENT MODELLING

A CAPSTONE PROJECT REPORT

Submitted in partial fulfillment of the requirement for the award of the Degree of

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

by

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CERTIFICATE

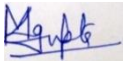
This is to certify that the Capstone Project work titled "**ANALYSIS OF AUXETIC STRUCTURES USING FINITE ELEMENT MODELLING**" that is being submitted by **KANTAMREDDI UMA MAHESH (17BME7081)** is in partial fulfillment of the requirements for the award of Bachelor of Technology, is a record of bonafide work done under my guidance. The contents of this Project work, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

Dr. V M Ravindra Kumar

Guide

The thesis is satisfactory

Approved by



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ABSTRACT

Auxetic structures are the cellular structures which are having negative poisson's ratio and demonstrate the unique behaviour of lateral expansion which is different from other structures.They laterally expand or contract if we apply tensile or compressive load. These structures are used in lightweight structures and impact energy absorption applications.These are good for various engineering applications in the field of aerospace, automobile , implantable devices, military protection equipment, actuators . The present study is focussed on the design and evaluating the poisson's ratio of Re-Entrant honeycomb structures using Finite Element analysis and the effect of Reentrant honeycomb structure's Geometry parameters on poisson's Ratio and Energy absorption .A Validation study of in-plane uniaxial compression loading behavior of Re-entrant Honeycomb structure.Numerical models have been developed using Ansys Workbench 2020 R2 Software . It has been observed that with the increase of H/L ratio ,poisson's ratio of the structure will be increased and Specific Energy absorbed by the structure will be decreased.With the increase of Re-entrant angle poisson's ratio of the structure will be decreased and Specific Energy absorbed by the structure will be increased.

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CHAPTER 1
INTRODUCTION

The use of auxetic and non-auxetic materials in blast resistant structures had been used by developers.If any material is stretched,there is reduction in width and increment in length.That's why those types of materials are having positive poisson's ratio.This dimensional change can be calculated by Poisson's ratio.The ratio between lateral strain to longitudinal strain is called Poisson's ratio. Longitudinal strain means "Strain in the direction of the applied load".Lateral strain means " Strain in the direction perpendicular to the applied load".

The analysis of auxetic structures can be done by software's like NX, CAD, CREO, CATIA, solid works. In this project, I used Ansys Design Modular as our design software. The analysis has been developed using Ansys Workbench 2020 R2 Software .

The present study is focussed on the design and evaluating the poisson's ratio of Re-Entrant honeycomb structures using F.E.A and the effect of the impact of Reentrant honeycomb structure's Geometry parameters on poisson's Ratio and Energy absorption .A Validation study of in-plane compression loading behavior of Re-entrant Honeycomb structure.Numerical models have been developed using Ansys Workbench 2020 R2 Software .

1.1 Objective of present Study:

1. The present study is focussed on the design and evaluating the poisson's ratio of Re-Entrant honeycomb structures by using Finite Element analysis.
2. To Analyse the effect of Reentrant honeycomb structure's Geometry parameters on Poisson's Ratio and Energy absorption .
3. A Validation study of in-plane uniaxial compression loading behavior of Re-entrant Honeycomb structure.

1.2 Organization of the Report

The remaining chapters of the project are described as follows.

- Chapter 2 contains the Literature survey
- Chapter 3 contains the Methodology
- Chapter 4 discusses the result obtained after the project was implemented
- Chapter 5 concludes the report

CHAPTER 2
LITERATURE SURVEY

2.1 Literature Review based on various research papers

Auxetic materials are known for their special behaviour ; in contrast to traditional the thickness of these materials increments under the activity of tensile or compressive loading. The present status of exploration on auxetic materials (negative Poisson's proportion) is evaluated, with specialization in viewpoints pertinent to advanced plane design. Advancements in the displaying, plan, creation, testing and likely utilizations of auxetic cell solids, polymers, composites and sensors/actuators are introduced.We know that the negative Poisson's ratio to which the thickness of the body increases when it is pulled or pushed along the axis.

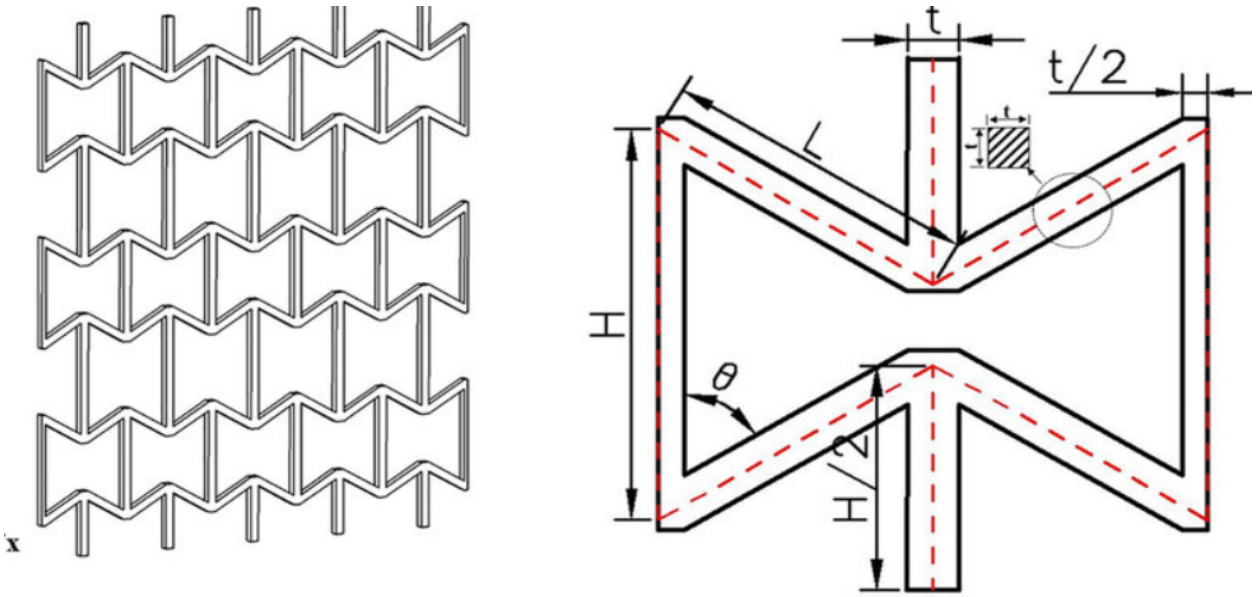


Figure 1:Re Entrant structure

CHAPTER 3
METHODOLOGY

I collected the various types of auxetic structures reported in literature recently.After that I collected the mechanical properties of base material through literature.I created Reentrant structure and gave the material properties to perform a mechanical analysis using Finite Element Modelling.I evaluated poisson's ratio of the structure and energy absorption by the structure .After that I changed the Re Entrant auxetic structure geometrical parameters and I analysed the effect of Reentrant honeycomb structure's Geometry parameters on poisson's ratio and Energy absorption.

Figure 2:Single Unit Cell

The Reentrant Honeycomb structure's single unit cell (Figure 1)is created by changing various geometrical parameters as shown in Table1.The model was kept in between two plates. Fixed supports are inserted one side.Application of displacement is done on other side equally.I applied compressive loading conditions on all the structures using Ansys Workbench 2020 R2 as shown in figure 6 &7. The boundary conditions used in these models are indicated as shown in Figure 6&7, to perform the compression tests by giving load in y-direction.The top plate was only allowed to move in y-direction for a displacement of 14 and calculated elongation in axial direction and transverse deformation.I used a 5mm mesh element size with tetrahedral mesh as shown in figure 5. I selected Stainless steel 316 L .The young's modulus of this material is 197GPa and poisson's ratio value is 0.267.

Sl.No	Re-Entrant Angle(deg.)	H(mm)	L(mm)	H/L
1	45	7.5	03	2.5
2	50	08	3.5	2.28
3	60	06	03	02
4	70	12	6.25	1.92
5	75	14	7.5	1.86

Table 1:Various Geometrical Parameters of Reentrant Honeycomb Structure

The geometrical parameters like aspect ratio and re-entrant angle have great impact on the properties of auxetic structures. The following geometries are analysed using Ansys Workbench 2020 R2.The geometries of every structure is shown in figure 2,3,4

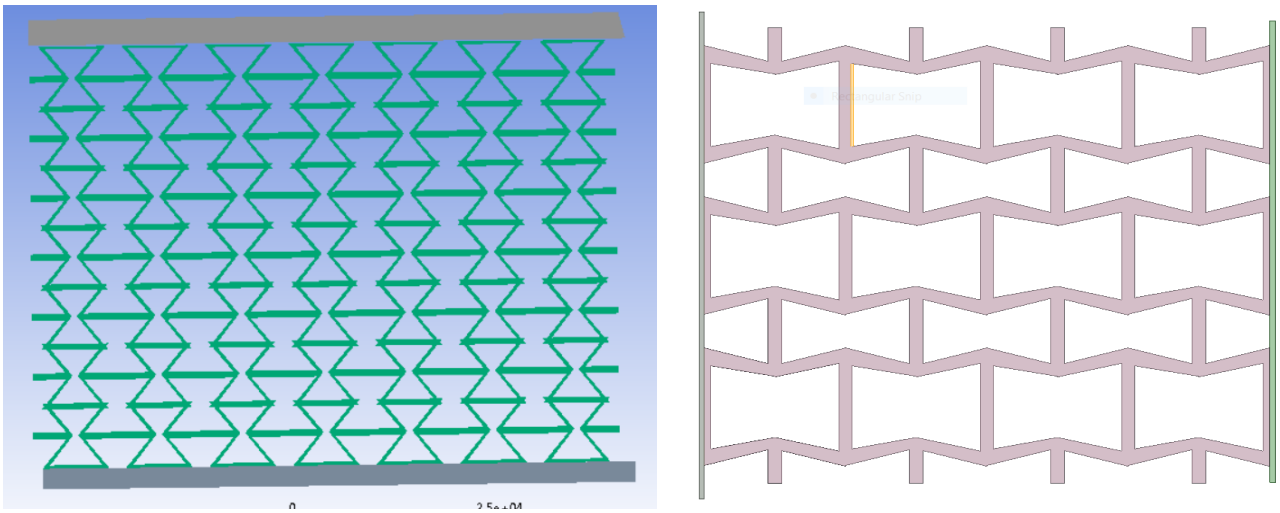


Figure 3&4 : Reentrant Honeycomb Structure

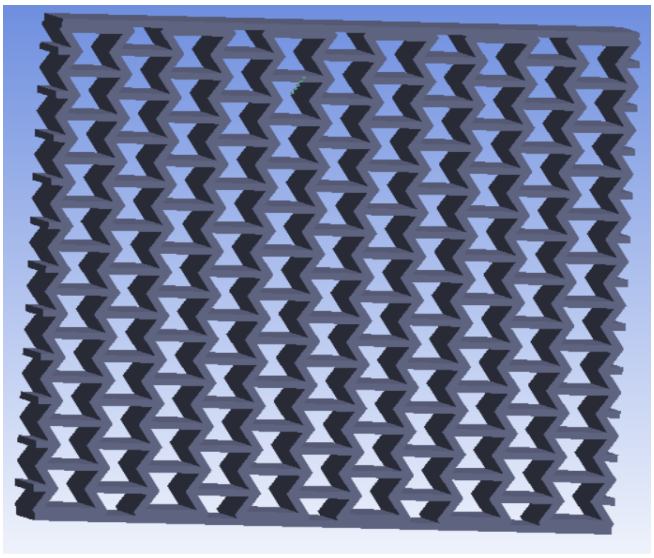


Figure 5:Reentrant honeycomb structures

Figure 6:Reentrant structures mesh

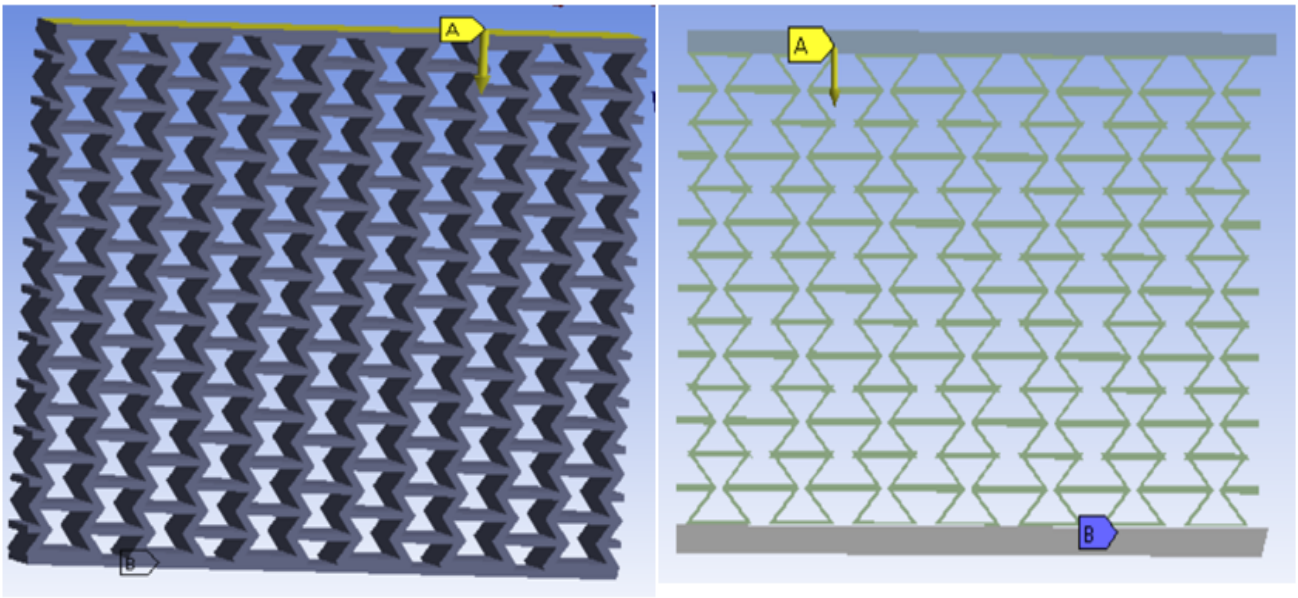


Figure 7 &8 :Displacement(14mm) boundary Conditions

Material	Modulus of Elasticity	Poisson's Ratio	Density	Yield Strength
Stainless Steel 316L	197GPa	0.267	8000 kg/m^3	543Mpa

TABLE 2:Material Properties of Stainless Steel 316 L

CHAPTER 4
RESULTS & DISCUSSION

Validation study is done on Reentrant auxetic honeycomb structure by taking one research paper.The Results are shown in figure 8,9.The re-entrant honeycomb structures have been designed by changing Geometrical parameters and calculated the poisson's ratio and energy absorbed by the structure.To analyse the effect of Reentrant honeycomb structure's Geometry parametres on poisson's Ratio and Energy absorption .I have fixed Reentrant angle and design the auxetic structures with different H/L ratio and poisson's ratio and energy absorbed by the structure .In the same way I fixed the H/L Ratio and design the auxetic structures with different Re entrant angles. The geometries of auxetic structures can be seen in Table 5.

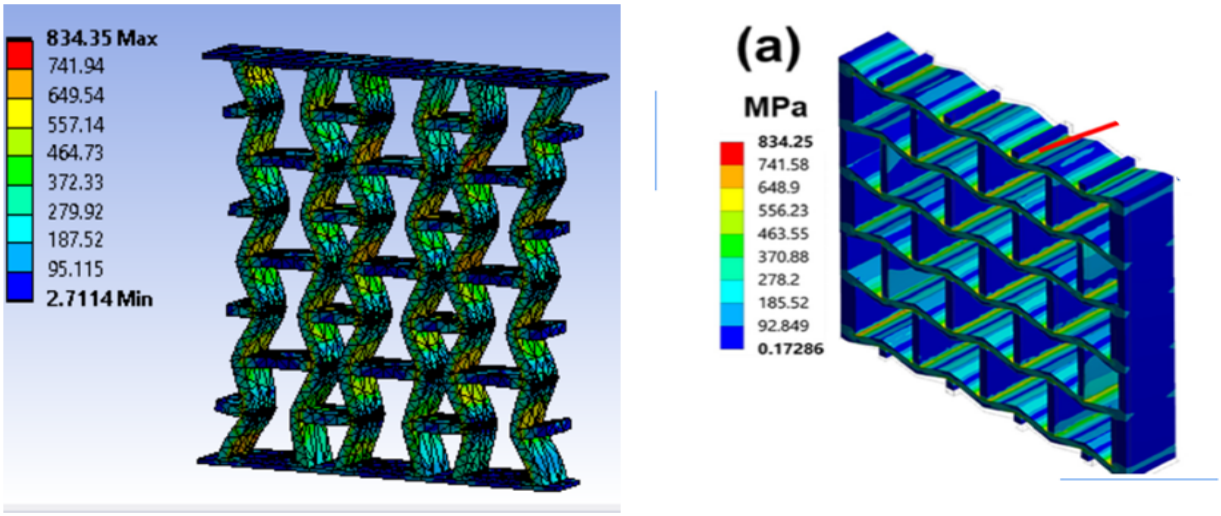
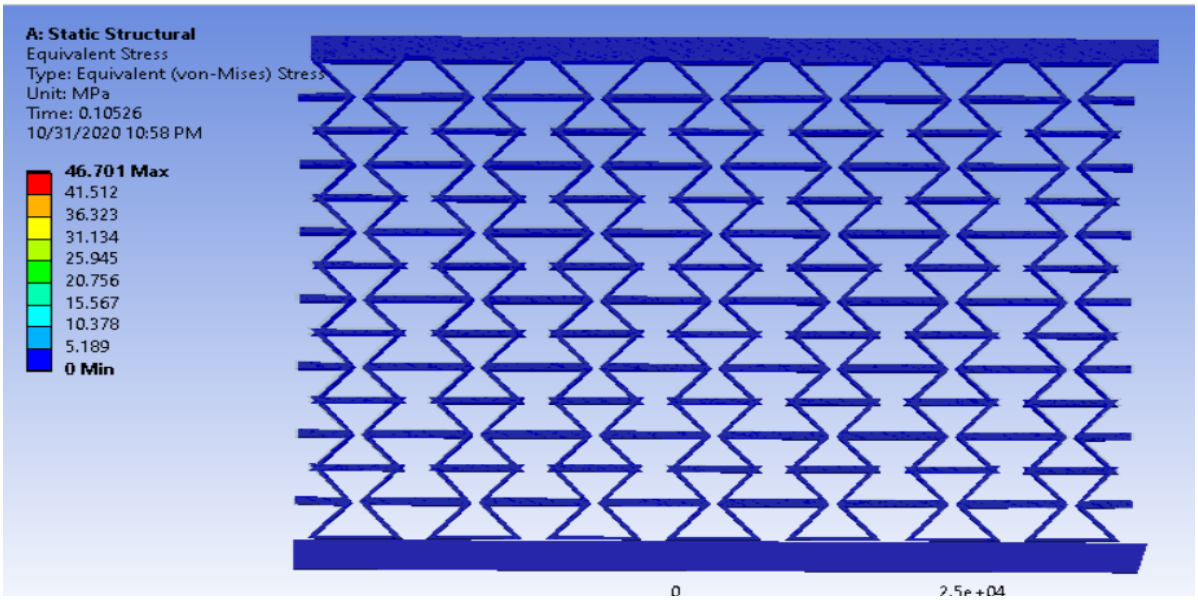


Figure 9,10&11:Von Mises Stress contour plot validation study



The Stress Vs Strain graphs also plotted to evaluate the energy absorption.I have taken linear elastic material properties.So that we will not get plastic deformation part in the stress Vs strain curve(Figure).The area under the Stress Vs Strain is called energy absorbed by the structure.
The displacement loading condition is applied on the top plate on the structure in Y-direction .This dimensional change may be calculated.The ratio between lateral strain to longitudinal strain is called Poisson's ratio. Longitudinal strain means "Strain in the direction of the applied load".Lateral strain means " Strain in the direction perpendicular to the applied load". The elongations of each model in all the directions is calculated and shown in Table 4.The deformation contour plots are shown in Figure

Reentrant Angle	X(mm)	Y(mm)	Z(mm)
50	17.904	11.63	0
60	0.16097	0.11836	0.0730
75	0.16939	0.14115	0.0179

Table 3: Elongation In all the directions

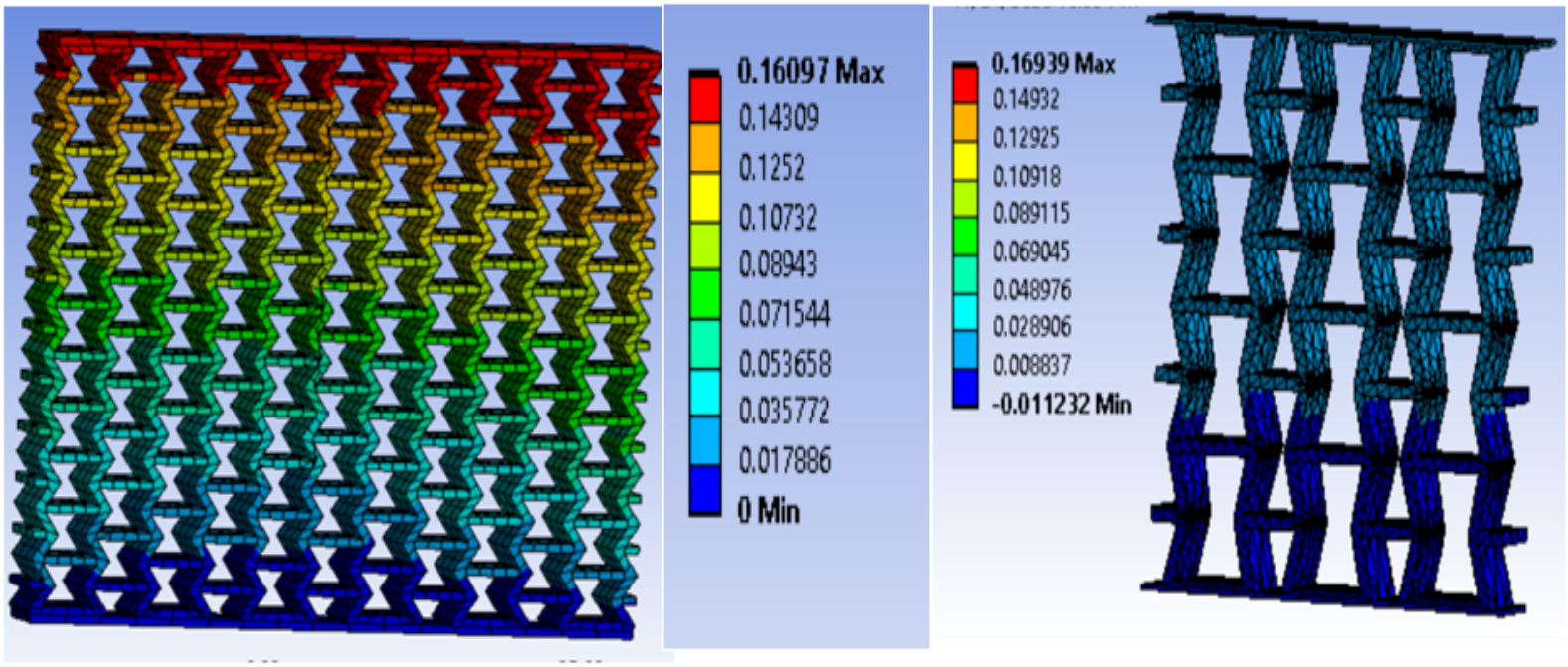


Figure 12 :Deformation Contour Plots

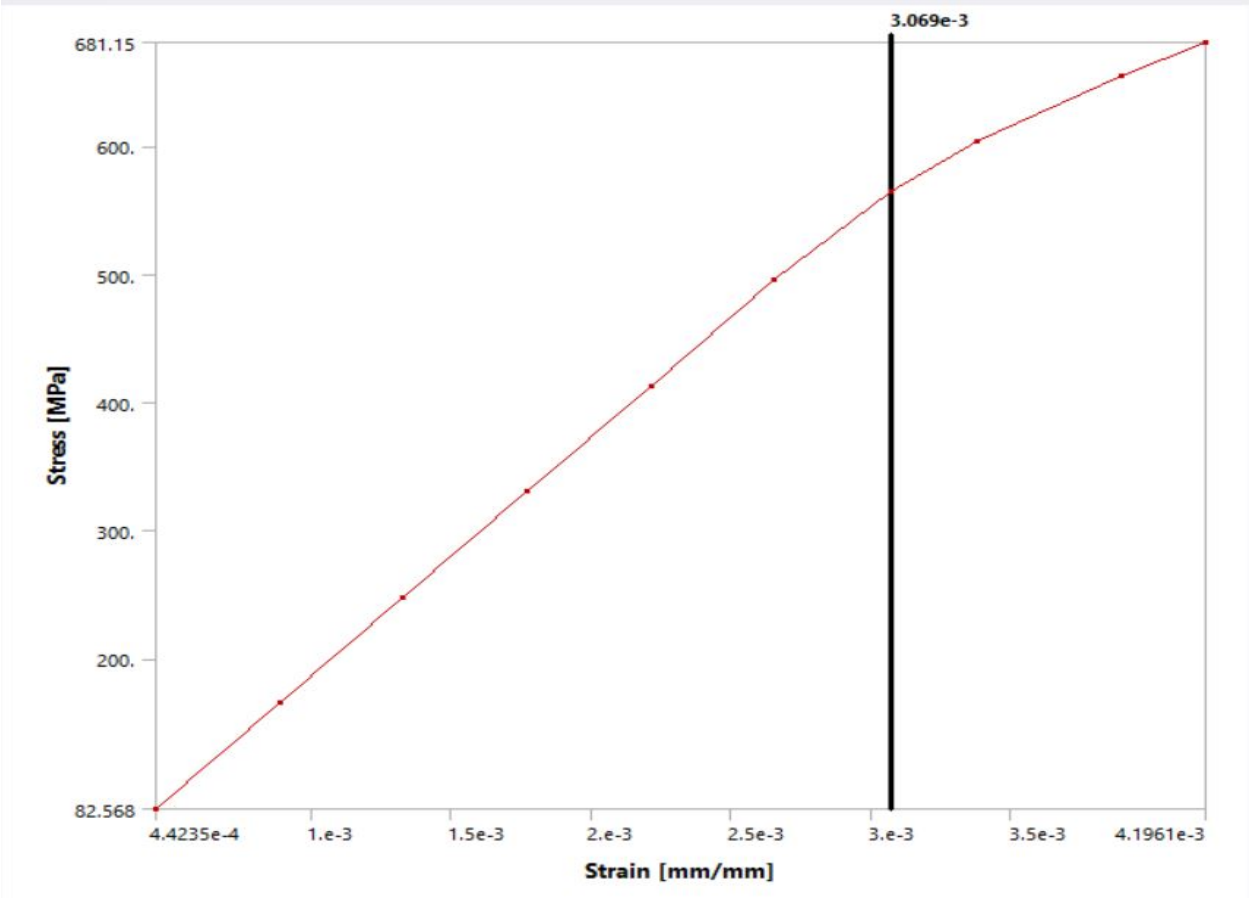


Figure 13:Stress Vs Strain(Validation Reentrant auxetic Structure)

Sl.No	Re-Entrant Angle	H/L Ratio	Poisson's Ratio	Energy Absorption(J/kg)
1	75	2.5	-1.67	123.56
2	75	2.28	-1.42	184.78
3	75	1.86	-1.20	233.75
1	50	1.86	-1.76	117.21
2	60	1.86	-1.59	167.76
3	75	1.86	-1.20	233.75

Table 4:Relationship between Reentrant Angle, H/L Ratio, and Possion's ratio

Sl.No	Re-Entrant Angle	H/L Ratio	Poisson's Ratio	Energy Absorption(J/kg)
1	45	2.5	-2.36	47.89
2	50	2.28	-1.54	66.96
3	60	02	-1.36	112.21
4	70	1.92	-1.28	146.79
5	75	1.86	-1.20	233.75

Table 5:Relationship between Reentrant Angle, H/L Ratio, and Possion's ratio

Re-Entrant angles influence the effective length of the structure . With The Increase of aspect Ratio ,Poisson's ratio of the structure will be increased Specific energy absorbed by the structure will be decreased.if Re-Entrant Angle increases, Poisson's ratio of the structure will be reduced Specific energy absorbed by the structure will be increased.Poisson's Ratio is calculated by using the above formula after calculating elongation in the X & Y direction.Energy absorbed by the structure is calculated from the Stress Vs Strain curve.

$$\upsilon_{xy} = -\frac{\varepsilon_{\text{true lateral}}}{\varepsilon_{\text{true axial}}}$$

CHAPTER 5
CONCLUSIONS AND FUTURE WORK

- Auxetic structures are the cellular structures which are having minus poisson's ratio and demonstrate the unique nature of lateral expansion which is different from other structures.
- In this work modelling and analysis of auxetic structures were done using ANSYS 2020 R2.
- I assigned Stainless Steel 316L to the geometry.
- I used linear elastic material properties.
- The Reentrant honeycomb structure's Geometry parameters will affect significantly on Poisson's Ratio and Energy absorption .
- With The Increase of H/L Ratio ,Poisson's ratio of the structure will be increased Specific energy absorbed by the structure will be decreased.
- With The Increase of aspect Ratio ,Poisson's ratio of the structure will be increased Specific energy absorbed by the structure will be decreased.
- if Re-Entrant Angle increases, Poisson's ratio of the structure will be reduced Specific energy absorbed by the structure will be increased.
- There is a large scope to design new Auxetic structures with different geometrical parameters and understand the compressive behaviour of those structures to use in various applications such as Defence,Aerospace,Medical Industries in future.

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Education:

Degree/Grade	Institution	Percentage(%)	Year of passing
B.Tech (Mechanical Engineering)	VIT-AP University	88.2	2021
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Secondary (High School)	Z.P.H.S Konthalam	92	2015

Projects:

1. **Estimation of Compressive behaviour of auxetic structures using FEM**
2. **Class Room Automation:** This project helps to detect movements if any unknown persons come to the classroom ,It will send a message to our phone using GSM module.The projector is operated by only teachers.There is a password for every feature.

Achievements & Co-Curricular Activities:

1. Class room automation project Secured best place (top 10)in EC Projects
2. Selected to pursue B-Tech in VIT- AP University under STARS Programme
3. Participated In Social Innovative challenge In V-TAPP 2019
4. Kabaddi Team captain of GJC
5. Attended 50 hours of job ready English course offered by ELS language centres
6. Secured Visakhapatnam District first Rank in Intermediate among government junior colleges in 2017