# Design, Fabrication and Testing of Flexure Mechanism

Sabbella Naga subba Lakshmi[1], Dr S. Sambhu Prasad[2] Mrs. B. Anusha[3]

[1]*M.Tech Student (CAD/CAM),Dept. of ME, Pragati Engineering College ,Surampalem , sumasabbella2121995@gmail.com*

[2]*Associate Professor Dept. of ME Pragati Engineering College,*

[3]*Associate Professor Dept. of ME Pragati Engineering College,anusha.b@pragati.ac.in*

***Abstract***

Flexure Mechanism is a recent development in the field of MEMS designing. It is a single-piece mechanism that transfers motion without any relative motion between joints or linkages, thus causing no friction or hysteresis loss. The design of a mechanism having flexural bending at the linkages methods for modelling and designing compliant mechanisms has spurred their use in a variety of products, ranging from macro-scale products such as clutches, guides, and switches, to micro-electromechanical systems (MEMS). This mechanisms offer a number of advantages, such as increased precision, reduced friction and wear, simple construction, and reduced assembly. In many ways this mechanisms have developed. Similar functionality to rigid mechanisms. Compliant mechanisms have the potential to completely eliminate relative motion between linkages, and thus eliminate friction

In this work a flexural mechanism are designed using data from the base paper and manufactured using 3d printing and are tested for flexibility, the flexibility is measured in terms of deformation under load and using a graph sheet setup, for fabricate the mechanism poly-lactic acid material is used, and is fabricated on a 3D printer, these models are developed using Catia v5. The results are validated using Ansys simulation results.

***Keywords****— compliant mechanism, Pseudo-rigid body models, Polylactic acid material, 3d printing, cura soft ware, Load, catia v5, Ansys.*

## 1. Introduction

A mechanism is a mechanical device used to transfer or transform motion, force, or energy. Traditional rigid-body mechanisms consist of rigid links connected at movable joints. Two examples are shown below. The linear input is transformed to an output rotation, and the input force is transformed to an output torque. As another example, consider the vice grips (shown in the right image). This mechanism transfers energy from the input (your hand) to the output (the gripper teeth). Since energy is conserved between the input and output (neglecting friction losses), the output force may be much larger than the input force, but the output displacement is much smaller than the input displacement. Structures may also consist of rigid links connected at joints, but relative motion is not allowed between the links. Since a structure does not have mobility, it does not perform work, and is usually not considered to be a mechanism.

Mechanisms are all around us. There are many examples in automobiles, sports equipment, furniture, construction equipment, robotics, and almost anything that has moving parts.

### 1.1 Compliant Mechanism

A compliant mechanism is a mechanism that gains at least some of its mobility from the deflection of flexible members rather than from movable joints only. An example or a compliant crimping mechanism is shown below.

For the compliant crimping mechanism (shown below), the input force is transferred to the output port, much like the vice grips mechanism, only now some energy is stored in the form of strain energy in the flexible members. Note that if the entire device were rigid, it would have no mobility and it would be a structure.

Compliant mechanisms are all around us, from products we own to high-tech precision manufacturing equipment. You probably use many compliant mechanisms every day. Some examples include one-piece plastic lids (like the one on ketchup bottles), tape measures, battery clips, mouse buttons, and many snap-fit part

## 2.Objectives:

Flexure mechanism is designed by the data collected from the base paper and 5 different models are designed

1. The 3d designed models are tested for flexibility and flexibility is counted based upon the loads.

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2. Deformation in all the 5 models after applying loads are shown by settingup graph sheets
3. For fabricating the material polylactic acid material is used and model are developed in Catia.
4. The results are validated using Ansys simulation results

## Properties of Materials:

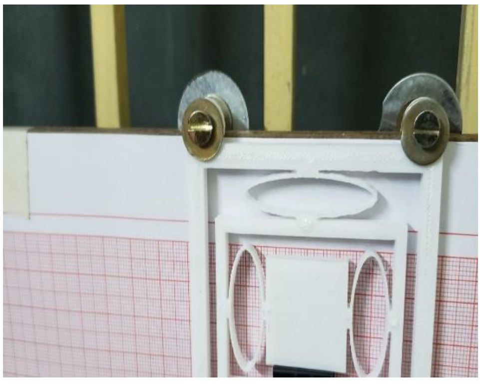
Polylactic acid or polylactide (PLA) is a thermoplastic aliphatic polyester derived from renewable resources. In 2010, PLA had the second highest consumption volume of any bioplastic of the world, although it is still not a commodity polymer. Its widespread application has been hindered by numerous physical and processing shortcomings. PLA is the most widely used plastic filament material in 3D printing.The name "polylactic acid" does not comply with IUPAC standard nomenclature, and is potentially ambiguous or confusing, because PLA is not a polyacid (polyelectrolyte), but rather a polyester

## 2.1. 3d Printing

3D printing process builds a three-dimensional object from a computer-aided design (CAD) model, usually by successively adding material layer by layer, which is why it is also called additive manufacturing, unlike conventional machining, casting and forging processes, where material is removed from a stock item (subtractive manufacturing) or poured into a mold and shaped by means of dies, presses and hammers.
The term "3D printing" covers a variety of processes in which material is joined or solidified under computer control to create a three-dimensional object, with material being added together (such as liquid molecules or powder grains being fused together), typically layer by layer. In the 1990s, 3D-printing techniques were considered suitable only for the production of functional or aesthetic prototypes and a more appropriate term for it was rapid prototyping. As of 2019 the precision, repeatability and material range have increased to the point that some 3D-printing processes are considered viable as an industrial-production technology, whereby the term additive manufacturing can be used synonymously with "3D printing". One of the key advantages of 3D printing is the ability to produce very complex shapes or geometries, and a prerequisite for producing any 3D printed part is a digital 3D model or a CAD file.

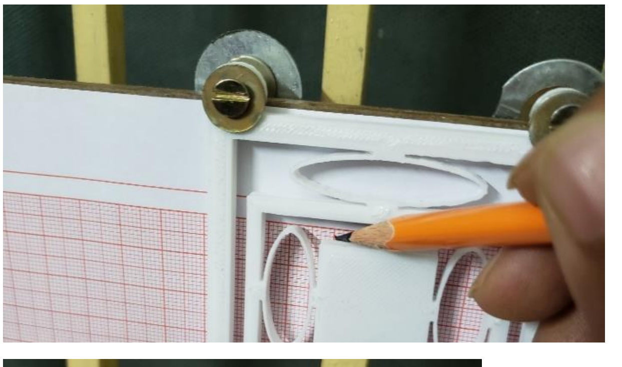
## 2.2 Cura software

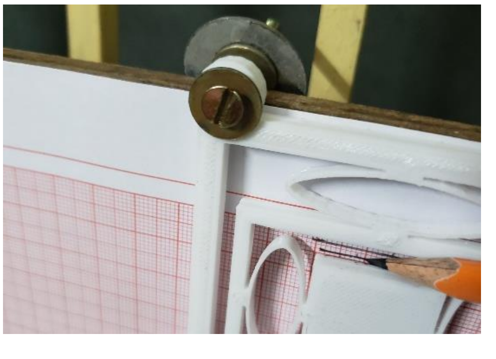
Cura is an open source 3D printer slicing application. It was created by David Braam who was later employed by Ultimaker, a 3D printer manufacturing company, to maintain the software. Cura is available under LGPLv3 license. Cura was initially released under the open source Affero General Public License version 3, but on 28 September 2017 the license was changed to LGPLv3. This change allowed for more integration with third-party CAD applications. Development is hosted on GitHub. Ultimaker Cura is used by over one million users worldwide, handles 1.4 million print jobs per week, and is the preferred 3D printing software for Ultimaker 3D printers, but it can be used with other printers as well.
Ultimaker Cura works by slicing the user's model file into layers and generating a printer-specific g-code. Once finished, the g-code can be sent to the printer for the manufacture of the physical object.
The open source software, compatible with most desktop 3D printers, can work with files in the most common 3D formats such as STL, OBJ, X3D, 3MF as well as image file formats such as BMP, GIF, JPG



**Levelling the test rig based board**

**Anchoring the specimen to the base board**





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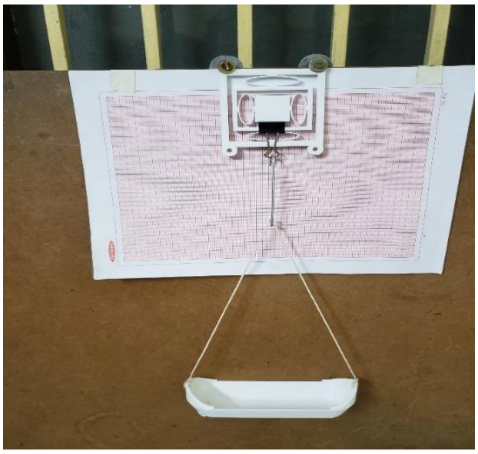
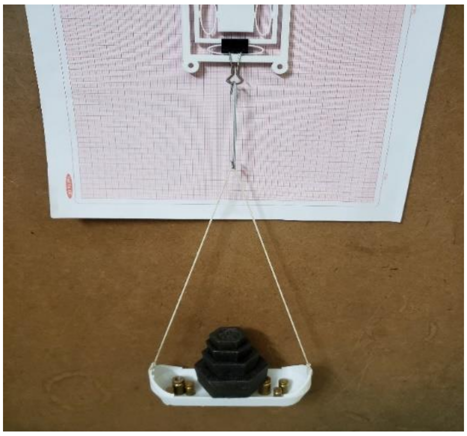
**Making intial position markings**

**Taking deformation markings**





**Loading setup**

**After applying the load**

The load applied is 950 grams it is around 9.31 Newtons

Approximately.

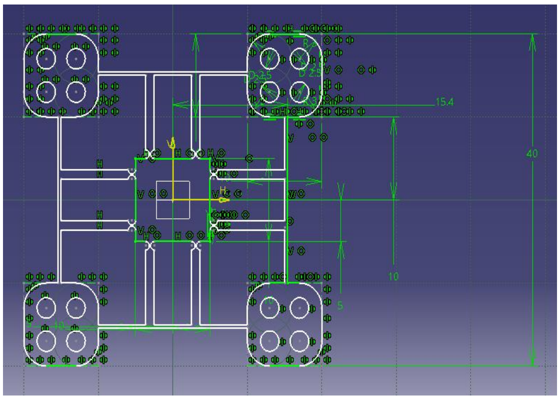
These experimentation is conducted on all the 3 specimens

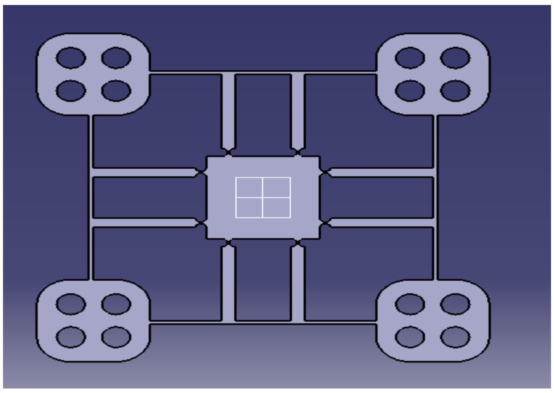
All the specimens are loaded both in x direction and y direction

## Design

### Catia:

CATIA which represents ComputerAidedThreeDimensionalInteractiveAplication is CAD programming possessed and created by Dassault Systems and promoted worldwide by IBM. It is the world's recommendation CAD/CAM programming for show and assembling. CATIA second complex station of result development through formularising, mean, designing and assembling. CATIA has a novel capacity of plan an item in the firm of its genuine conduct. This reason programming got productive since of its innovation which encourages its clients to enhance an untried vigorous, parametric, structure based standard reliably. Four Piston rod assembly were made by using CATIA which were shown in the fig below. In this for two different collars one cylinder piston rod was used.



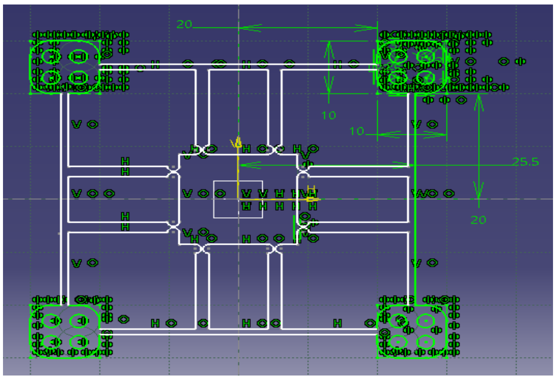


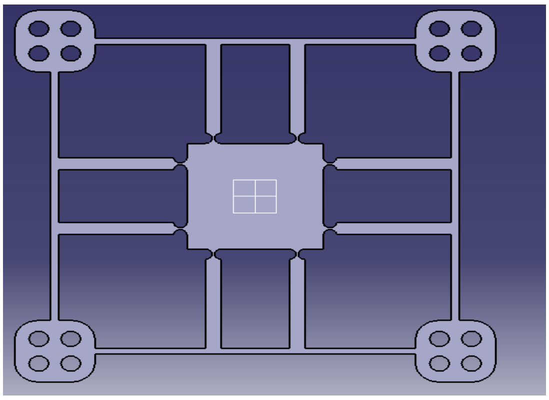
**Model 1**

**Model 1**

**2D model**

**3D model**



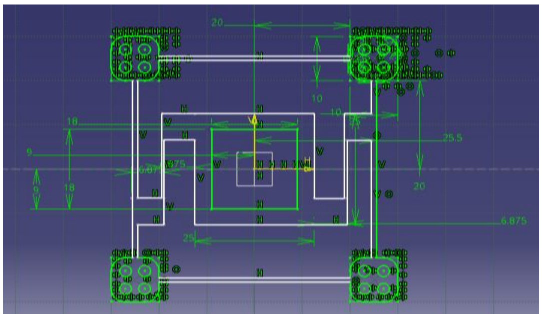


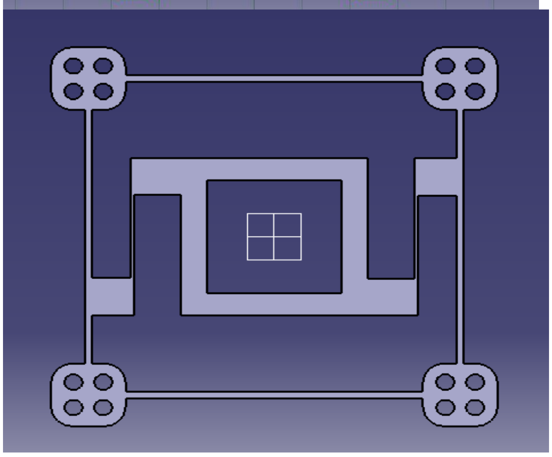
**Model 2**

**Model 2**

**2D model**

**3D model**



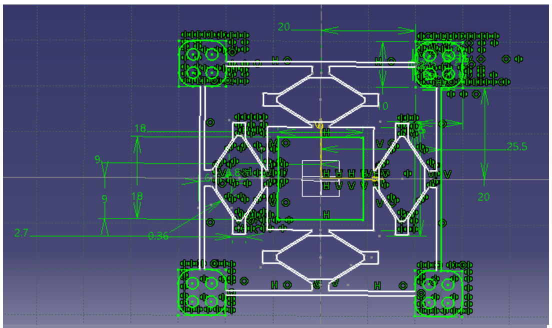


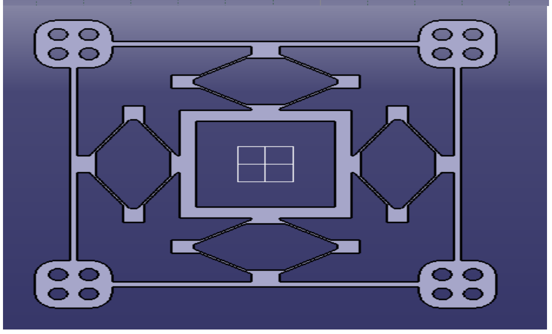
**Model 3**

**Model 3**

**2D model**

**3D model**



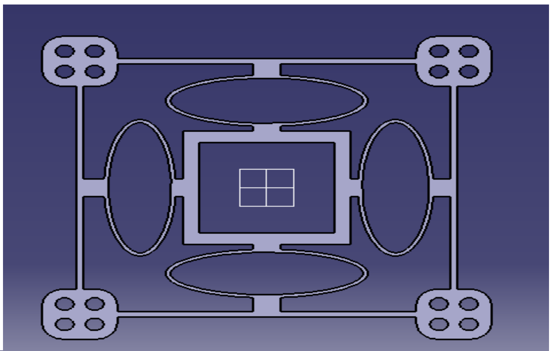


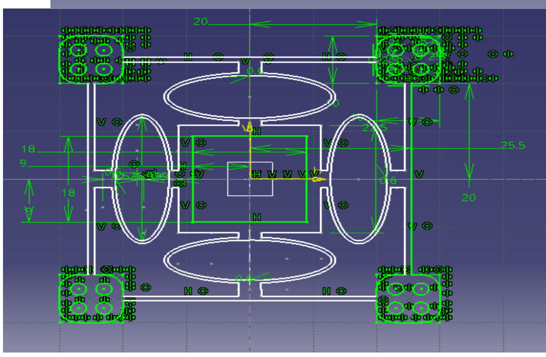
**Model 4**

**Model 4**

**2D model**

**3D model**





**Model 5**

**Model 5**

**2D model**

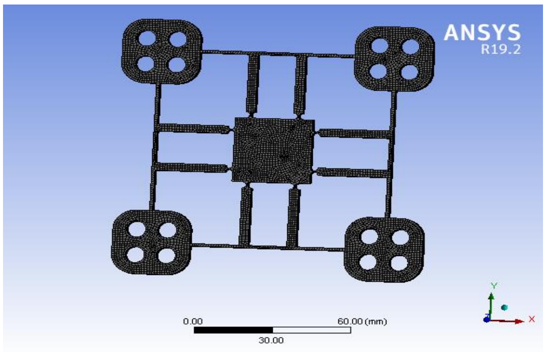
**3D model**

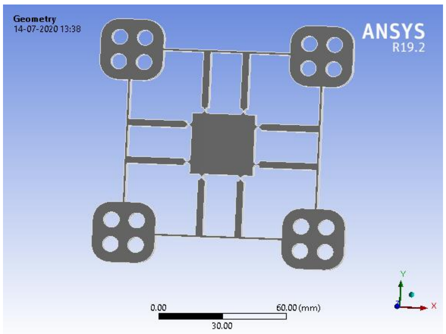
# Analysis

ANSYS is broadly useful programming, used to mimic connections of all controls of material science, basic, vibration, liquid elements, heat move and electromagnetic for designers. ANSYS can

import CAD information and empowers to construct a geometry with its "pre-preparing" capacities.
APDL is an abbreviation for ANSYS ParametricDesign Language, an incredible scripting language that enables you to parameterize your model and computerize normal assignments.
Ansys workbench rendition 19.2 has been utilized for the project to determine the Total deformation, Equivalent stress and Equivalent elastic strain for totally four cases with three different materials for further comparative analysis. In this analysis the four models were meshed and loads were applied according to the Objectives. In that especially the three and four models were shown better results than the other some of the analysis were shown below.

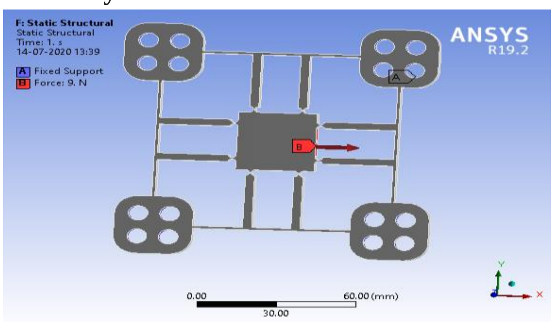
**Structural analysis of Model 1 in x direction**

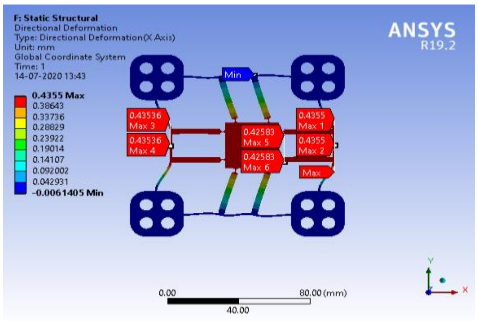


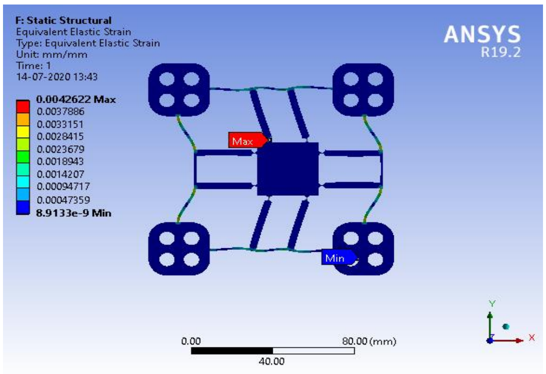

**Meshing**

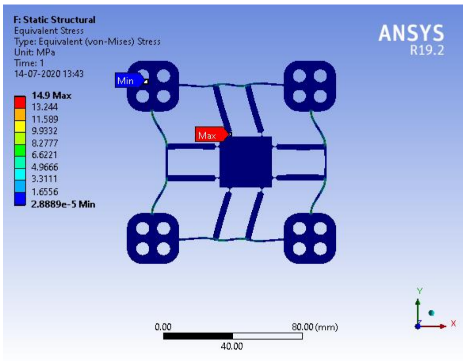
**Geometry**



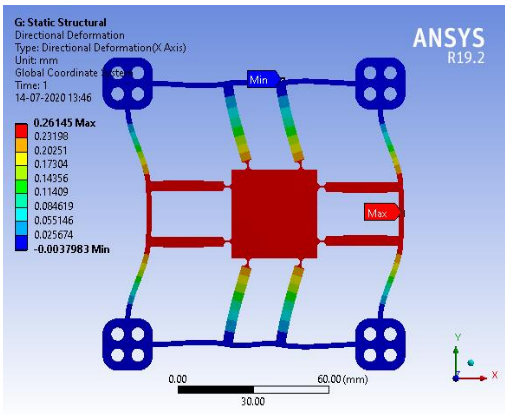

**Directional deformation directional deformation**

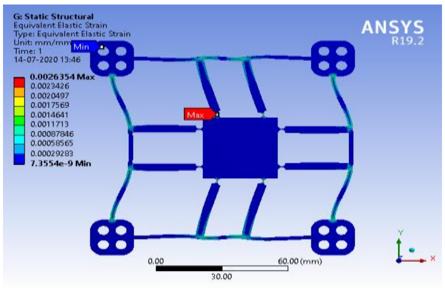


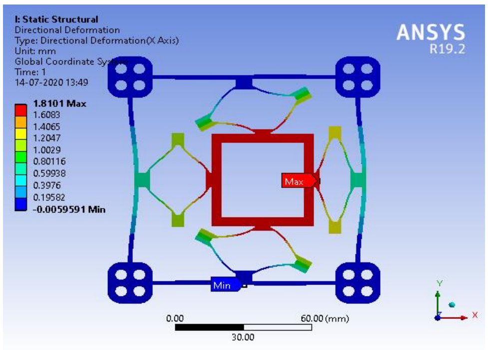




**Equivalentelasticstrain Equivalentelasticstrain**

**Structural analysis of model 2 in X direction**

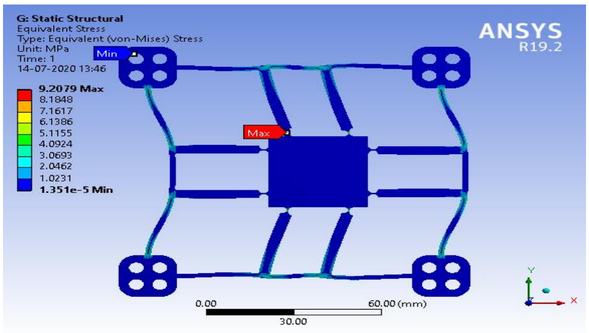




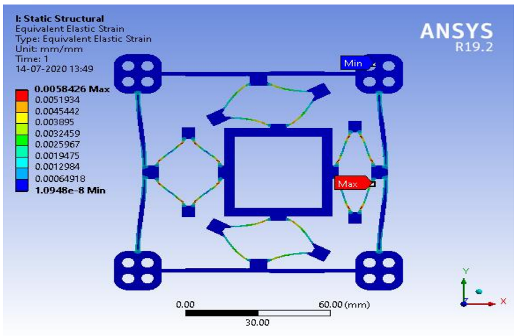

Directional Deformation

Equivalent elastic strain



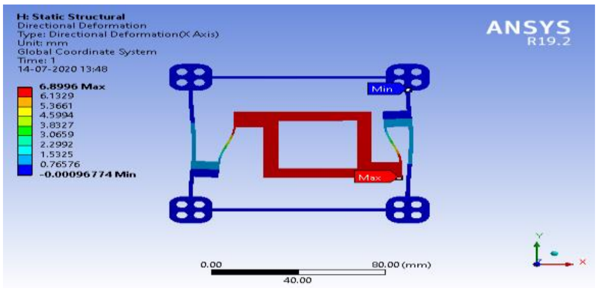

Equivalent stress

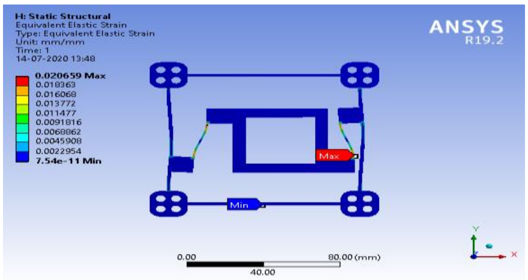
Structural analysis of model 3 in x direction




Directional deformation

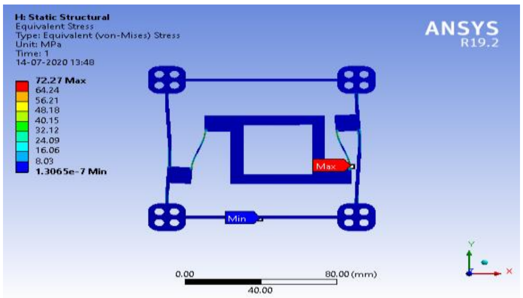
Equivalent elastic strain



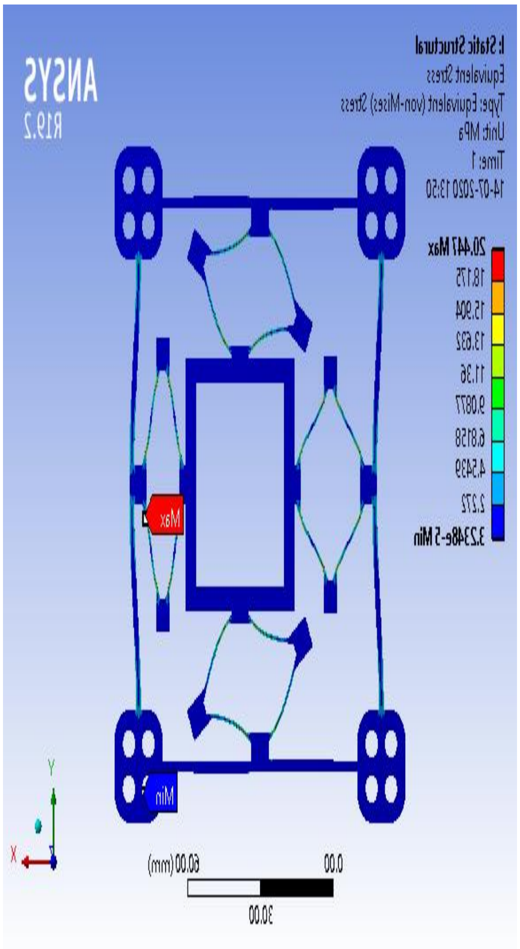

Directional deformation

Eqivalent elastic strain



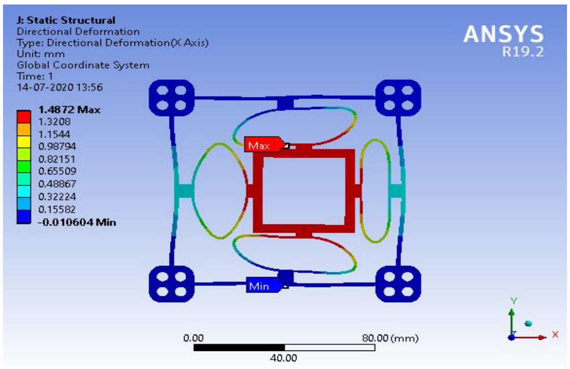

Equivalent stress

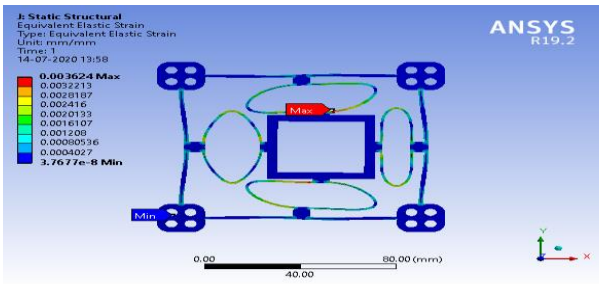
Structural analysis of model 4 in x direction



Equivalent stress

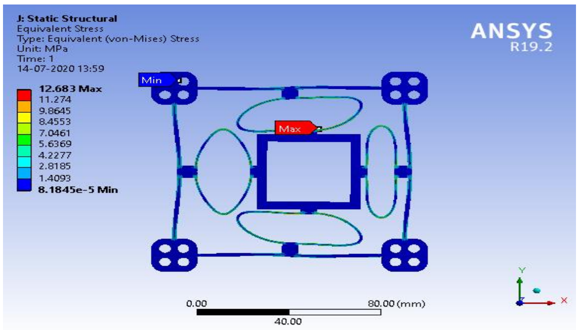
## Structural analysis of model 5 loading in x direction



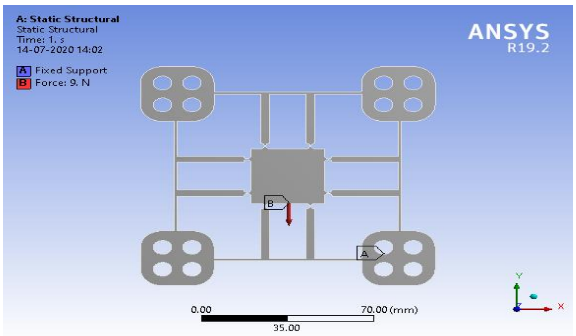

Directional deformation

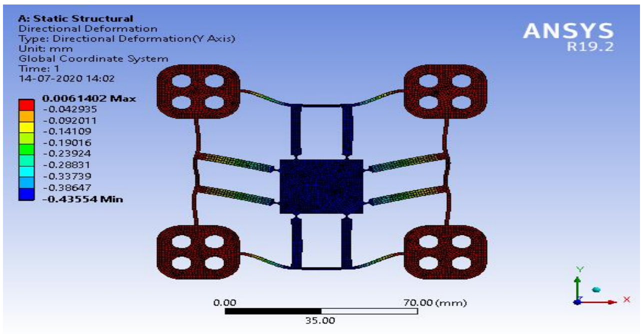
Equivalent elastic strain




Equivalent stress

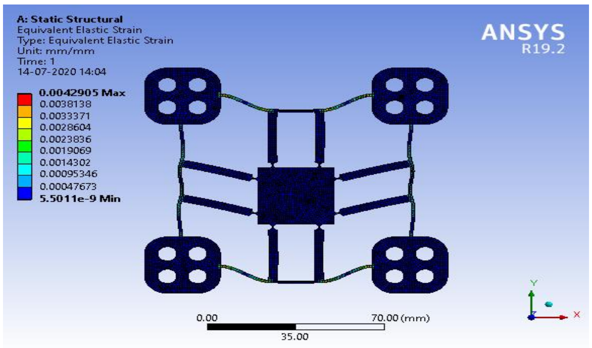
## Structural analysis of model 1 loading in y direction

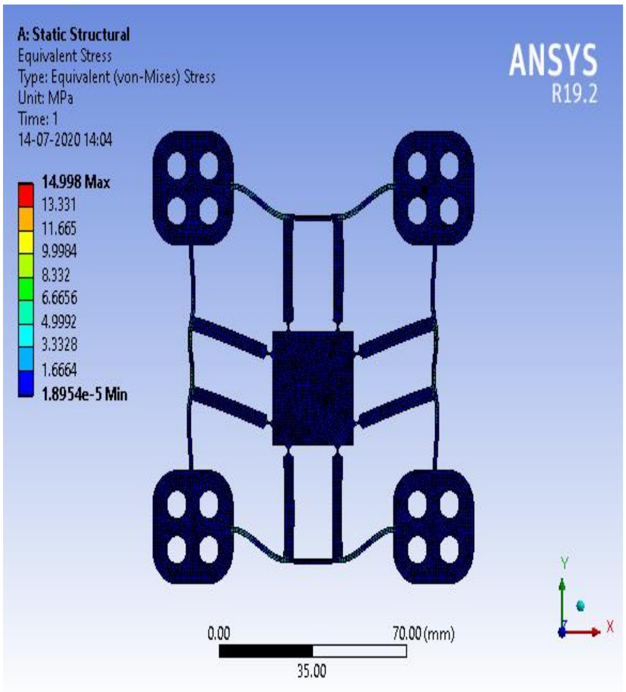



Loading in y direction

Directional deformation




Equivalent elastic strain

Equivalent stress

## Structural analysis of model 2 loading in y direction

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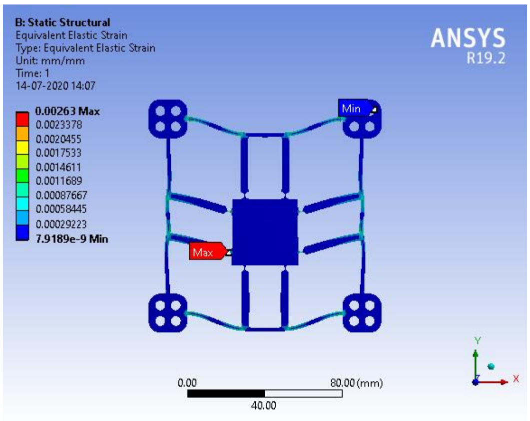
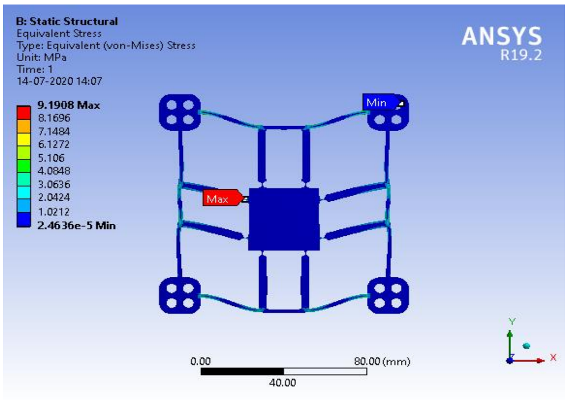
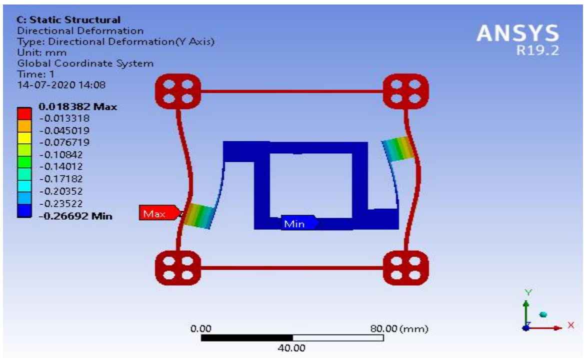


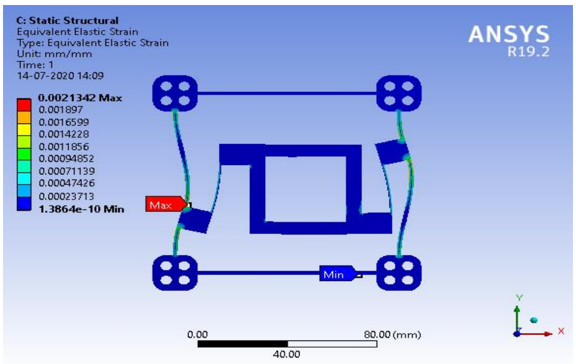




Directional deformation

Equivalennt stress

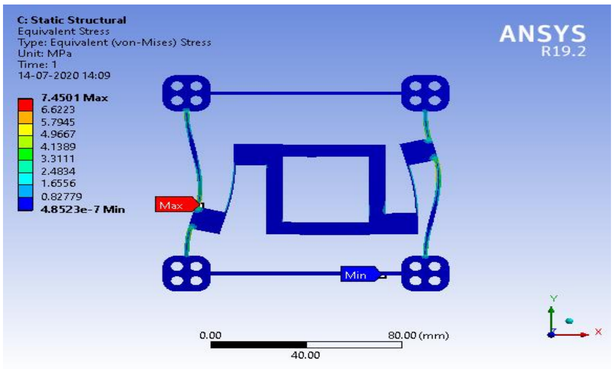
## Structural analysis of model 3 loading in y direction



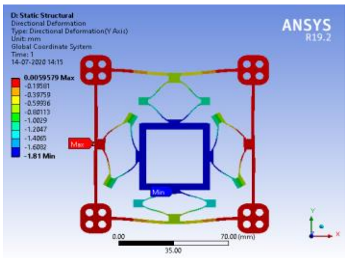

Directional deformation

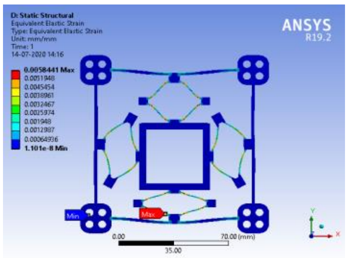
Equivalent elastic strain

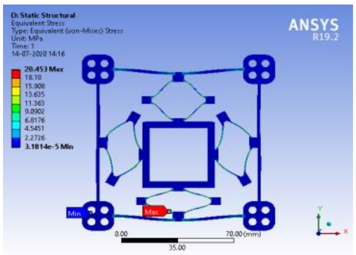



Equivalent stress

## Structural analysis of model 4 loading in y direction

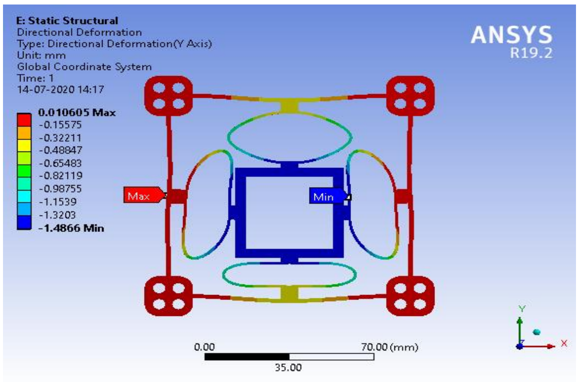


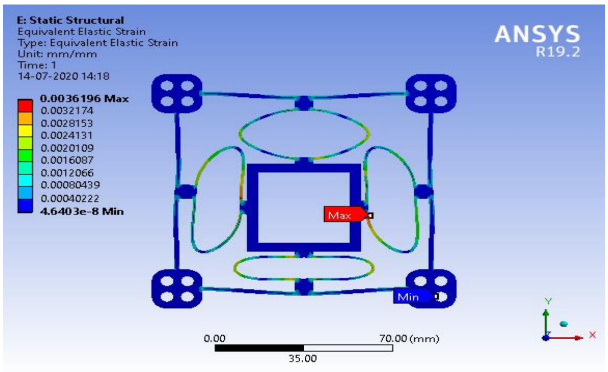




Directional deformation Equivalent elastic strain Equivalent stress

## Structural analysis of model 5 loading in y direction

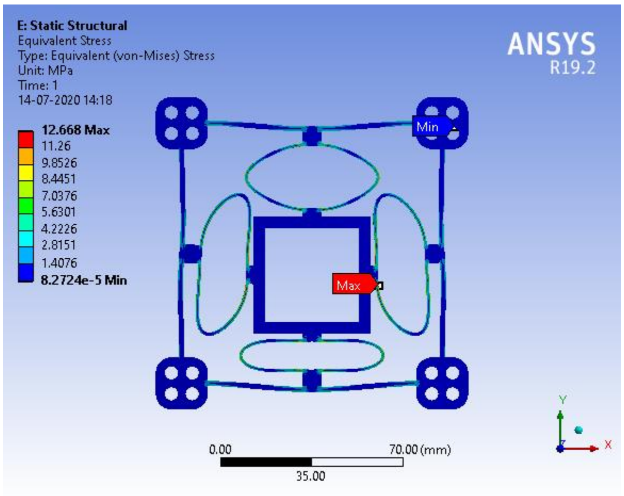



| loading in Y direction | directional deformation (MM) | | equivalent elastic strain (MM/MM) | | equivalent stress (Mpa) | |
|---|---|---|---|---|---|---|
| | Max | Min | max | min | max | Min |
| model 1 | 0.43554 | 0.00614 | 0.004291 | 5.50E-09 | 14.998 | 1.90E-05 |
| model 2 | 0.26131 | 0.003778 | 0.0263 | 7.92E-09 | 9.1908 | 2.46E-05 |
| model 3 | 0.26692 | 0.018382 | 0.002134 | 1.39E-10 | 7.4501 | 4.85E-07 |
| model 4 | 1.81 | 0.005958 | 0.005844 | 1.10E-08 | 20.453 | 3.18E-05 |
| model 5 | 1.4866 | 0.010605 | 0.00362 | 4.64E-08 | 12.668 | 8.27E-05 |

**Directional deformation**

**Equivalent elastic strain**




**Equivalent stress**

## 3.Results:

The below shown tables are the values of four models for three different materials which were compared according to the total deformation, equivalent elastic strain, equivalent stress

## Tables of structural analysis of complaint

## models loading in x direction

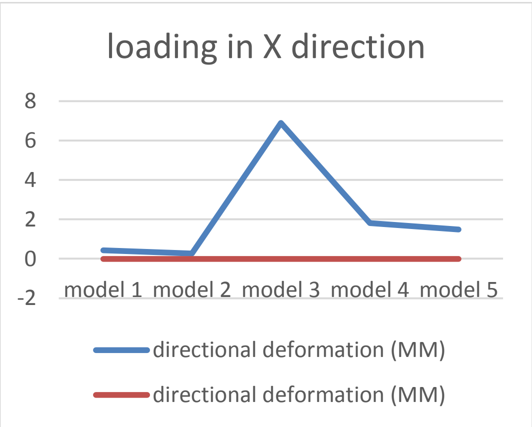
| loading in X direction | directional deformation (MM) | | equivalent e (MM/ |
|---|---|---|---|
| | max | min | max |
| model 1 | 0.43555 | -0.00614 | 0.00426 |
| model 2 | 0.26145 | -0.0038 | 0.00263 |
| model 3 | 6.8996 | -0.00097 | 0.02065 |
| model 4 | 1.8101 | -0.00596 | 0.00584 |
| model 5 | 1.4872 | -0.0106 | 0.00.362 |

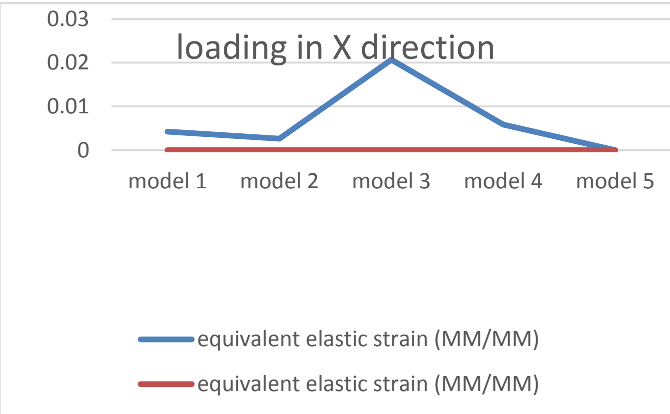
## Tables of structural analysis of complaint models loading in y direction Experimental values

| all dimensions in MM | loading in X direction | loading in Y direction |
|---|---|---|
| model 1 | 0 | 0 |
| model 2 | 1 | 1 |
| model 3 | 1 | 8 |
| model 4 | 4 | 4 |
| model 5 | 5 | 5 |

**Graphical representation of directional deformation**

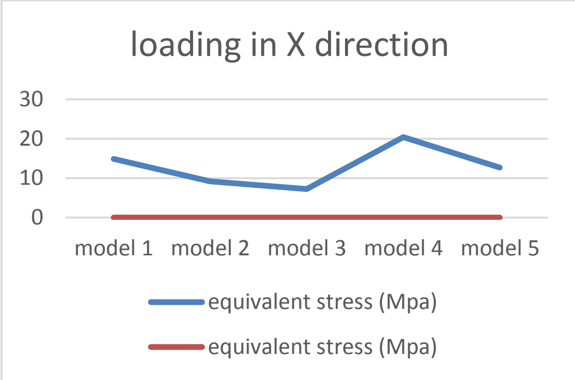
**Graphical representation of equivalent strain**

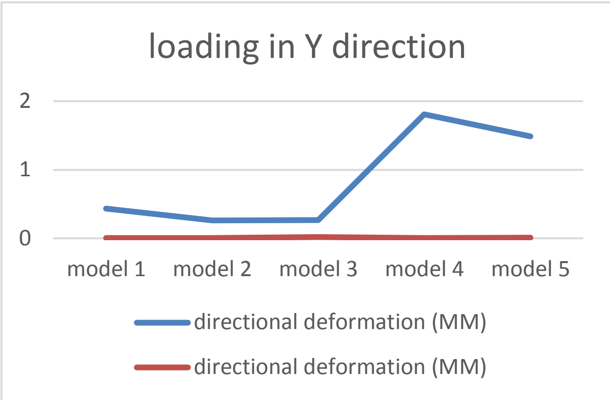



**Graphical representation of equivalent stress**

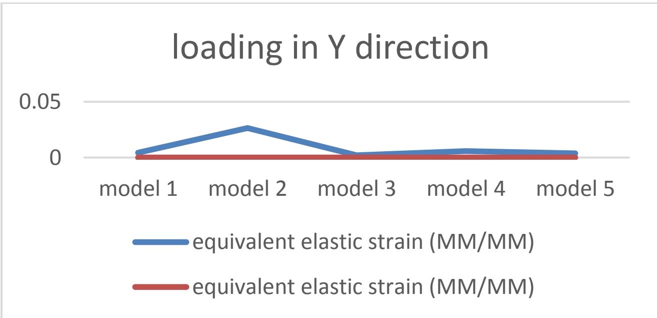
**Graphical representation of directional deformation**

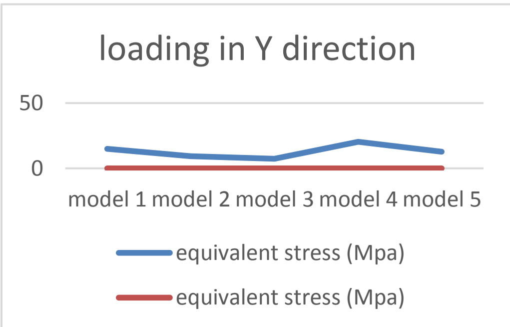



**Graphical representation of equivalent strain**

**Graphical representation of equivalent stress**




## Conclusions

Manufacturing compliant mechanisms using 3d printing is a good idea according to the custom requirement, but due to material limitations the application of 3d printing in manufacturing complaint mechanisms may be limited. Here in this project the applicability of 3D printing is studied by manufacturing different models of complaint mechanisms and testing there flexibility.

1. The flexibility in base model (model 1) is almost zero this is due to creep while printing and minor inaccuracies in the code.
2. The modified model (model 2) is a little better with minimalistic moment
3. The results from the simulation are also similar but little high when compared with experimental values
4. As the deformations are more the stress are also more in the model 3,4,5 .
5. Complaint mechanisms can be designed and manufactured using 3d printing based up the required motions.

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