Indian Institute of Technology Gandhinagar

Mechanics of Solids
ES 221

Course Project Summary Report

Group Number: **C1**
Group Name: **Complaint Stiffeners**

Project Title: **Binary Stiffness Mechanism**

20110133 Shubham Patel
20110132 Prey Patel
20110131 Kush Patel
20110161 Rajesh Kumar
20110137 Pearl Khare
20110157 Rahul Raj

April 10, 2022

Experimental Results

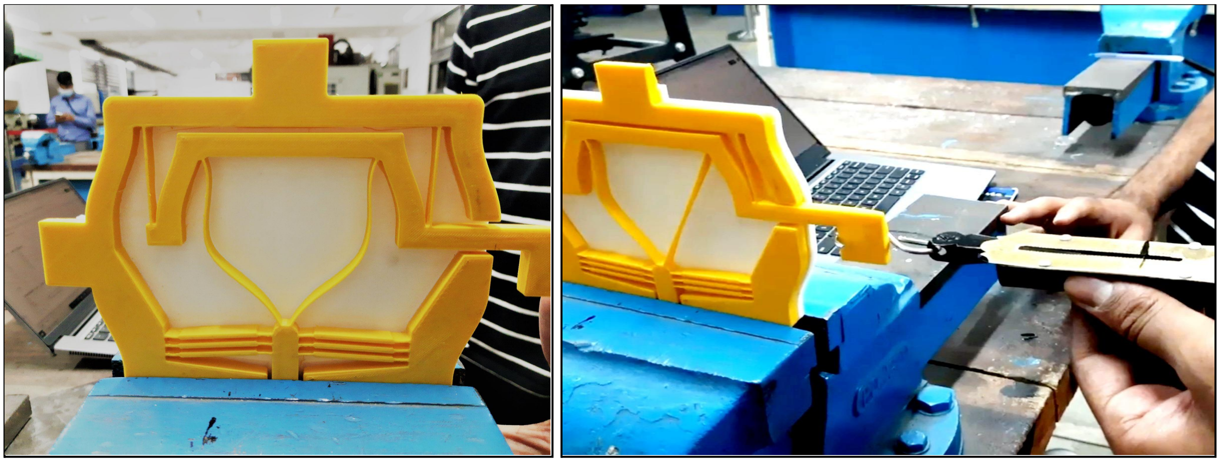

Figure 1: Experimental model before and after experiment

Details of experimental model development (material, fabrication, challenges):

- First task was to get the 3D CAD model of the desired structure. After that it was desired to 3D print. Different parts were 3D printed and then joined together to form the entire structure.
- It took 12 hours to build the first model. We then started trail experiments on it. Since due to constraints like small 3D printer size and tolerance of 3D printers, we had to make structures accordingly. So because of the small size of our model it was very delicate.
- We performed some experiments but while performing them, our structure broke. Due to some size of it this strength was very low.
- We then had to make one more structure. But now due to lack of PLA material in maker bhavan we had to use ABS 3D printing material. After the structure was printed, we noticed with ABS material that it was not perfectly good for the operation of the binary switch.

Experimental setup / Method of Performing test:

- We used Bench Vise to hold the structure.
- Force was applied through the spring balance so that applied force can be measured.
- Meter scale was used to measure displacement of horizontal beam.
- Then we took multiple readings to plot the graph.

Key Results (maximum load, deformation, stiffness etc.):

- Maximum load(for Parallel Flexure) = 0.5 kg & Stiffness = 0.32 N/m
- Maximum load(for Angled Flexure) = 0.12 kg & Stiffness = 0.31 N/m
- Load Range (for complaint mechanism) = 0 - 0.005 kg & Stiffness = 0.01 N/m

Key Experimental Findings (e.g., failure mode, was it same as expected etc.):

- The outcome of parallel flexure should be linear and we got nearly equal to linear graph and for angled flexure, complaint model also we got almost desirable shape.
- For overall complaint mechanism, the binary switch triggers almost at 1.7 kg load.

Analytical/Numerical Results

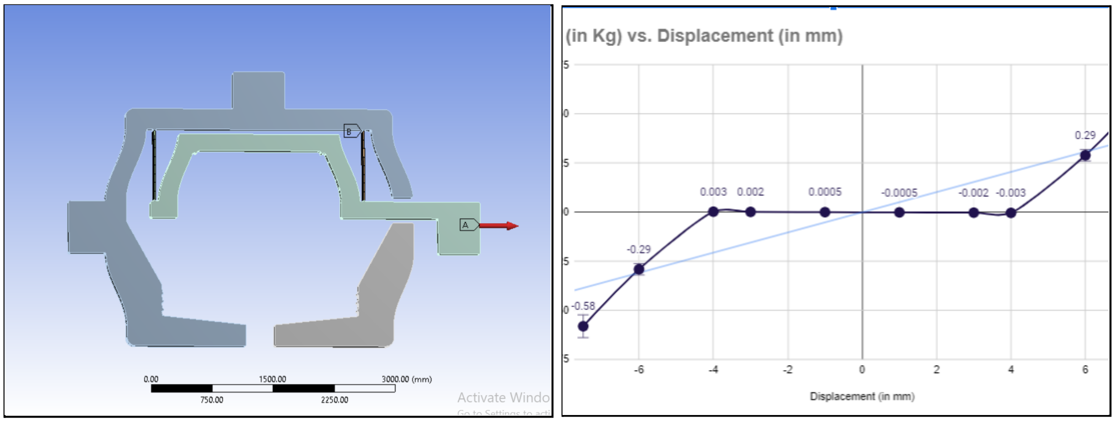

Figure 2: A view of numerical model and key result

Numerical/analytical model development (software, elements, materials):

- Software used: Autodesk Inventor Professional + Ansys 2019 R1
- ABS Plastic Material
  - Elastic modulus: 2.39E+09 Pa | Poisson's Ratio: 0.399
  - Tensile strength: 4.14E+ 07 Pa | Tensile Ultimate Strength: 4.13E+07 Pa
- Elements in Parallel Flexure Design:
  - Body   Parallel Flexures 1 and 2   Handle
- Elements in Angular Flexure Design
  - Handle   Angular Flexures (x2)   Switch
- The above two would be combined in order to obtain the final mechanism readings

Analysis procedure (Assumptions, material model, boundary conditions etc.):

- Assumptions: 1)Uniform distribution of material and its properties. 2) Gravity force is not being considered.
- The main frame is fixed, and the handle is constrained to horizontal translation. Force is applied in this constraint direction and the displacement is measured (for various values). Joints are fixed between flexible body (parallel flexure) and rigid body (body). And finally graph is plotted

Results (Peak force, peak displacement etc.):

- Peak Load (in zero stiffness region) = 0.003 kg
- Peak displacement (in zero stiffness region) = 4 mm
- Binary stable switch opens at 16N force

Key Findings (insights regarding the behavior of model, influence of assumptions etc.):

- The final Structure attains near zero stiffness for displacement ranging from -4mm to +4mm
- This is due to combined effect of angled blade flexures (having positive stiffness in this region) and parallel blade flexure (which has negative stiffness in this regions)

Comparison of Experimental and Analytical Results

Comparison of results (peak force, peak displacement etc.):

- We can notice that the difference between experimental results and analytical results are almost 0.05 kg and 0.05 N/m which are quite good and as expected.
- We are able to reduce the stiffness upto 98% - 99% by toggling the switch.

Reason for matching/mismatching of results:

- The main reason for little mismatching is uncontrolled condition and natural error. While measuring the displacement, there might be some error of 0.0001 - 0.001 mm due to tolerance of scale. While applying the force by spring balance, there is a natural tolerance present in spring because it is not perfectly elastic.
- On the other hand, in software, everything is ideal and highly accurate. So, even if we apply a load of 0.25 kg it means the load will be exactly the same as 0.25 kg.

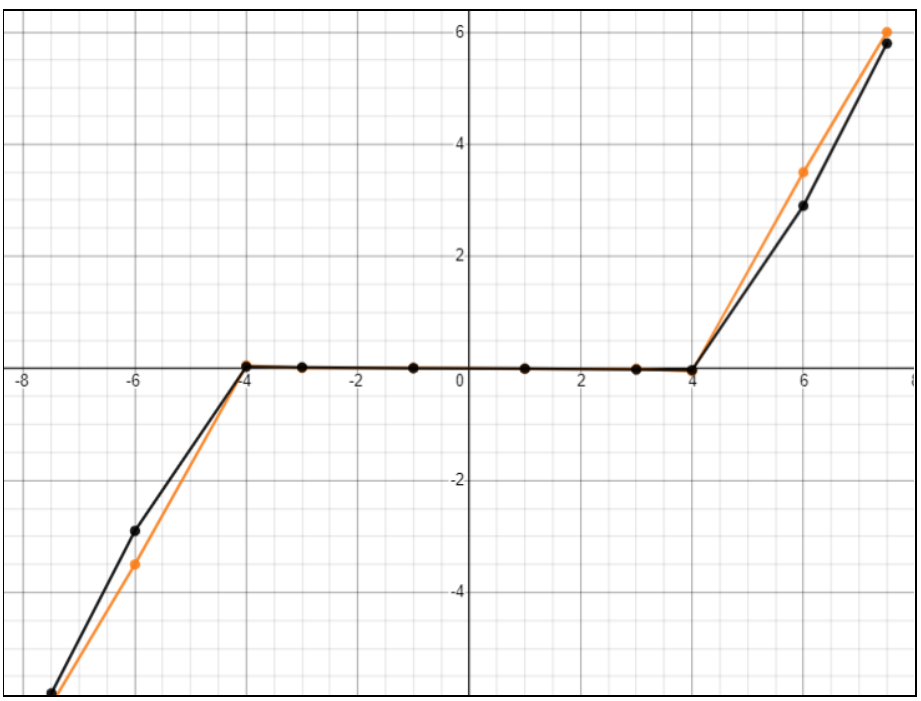

Figure: Comparison of experimental and analytical results

Scope of improvement in the simulation

- By reducing the mesh size, using high config system and network system processors, we can improve the simulations in ANSYS.