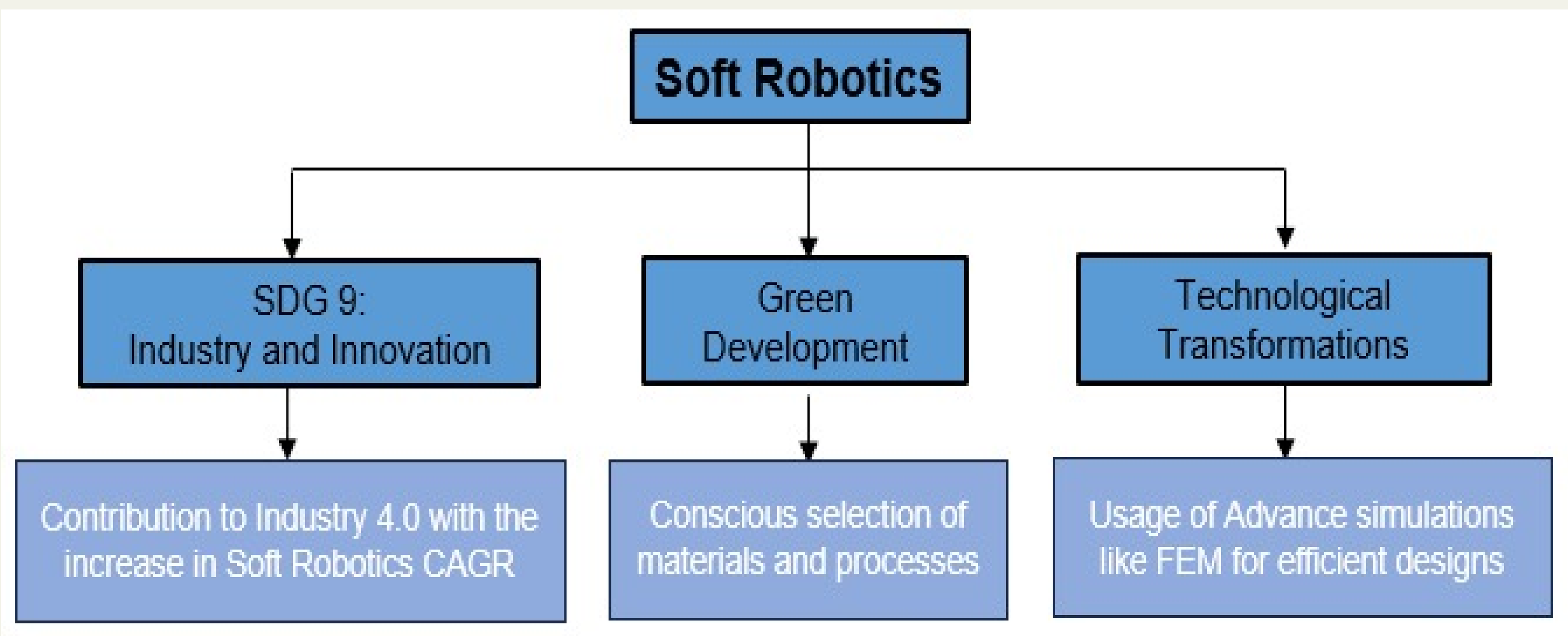
Design Optimisation of Soft Pneumatic Actuator

By Naman Khetan

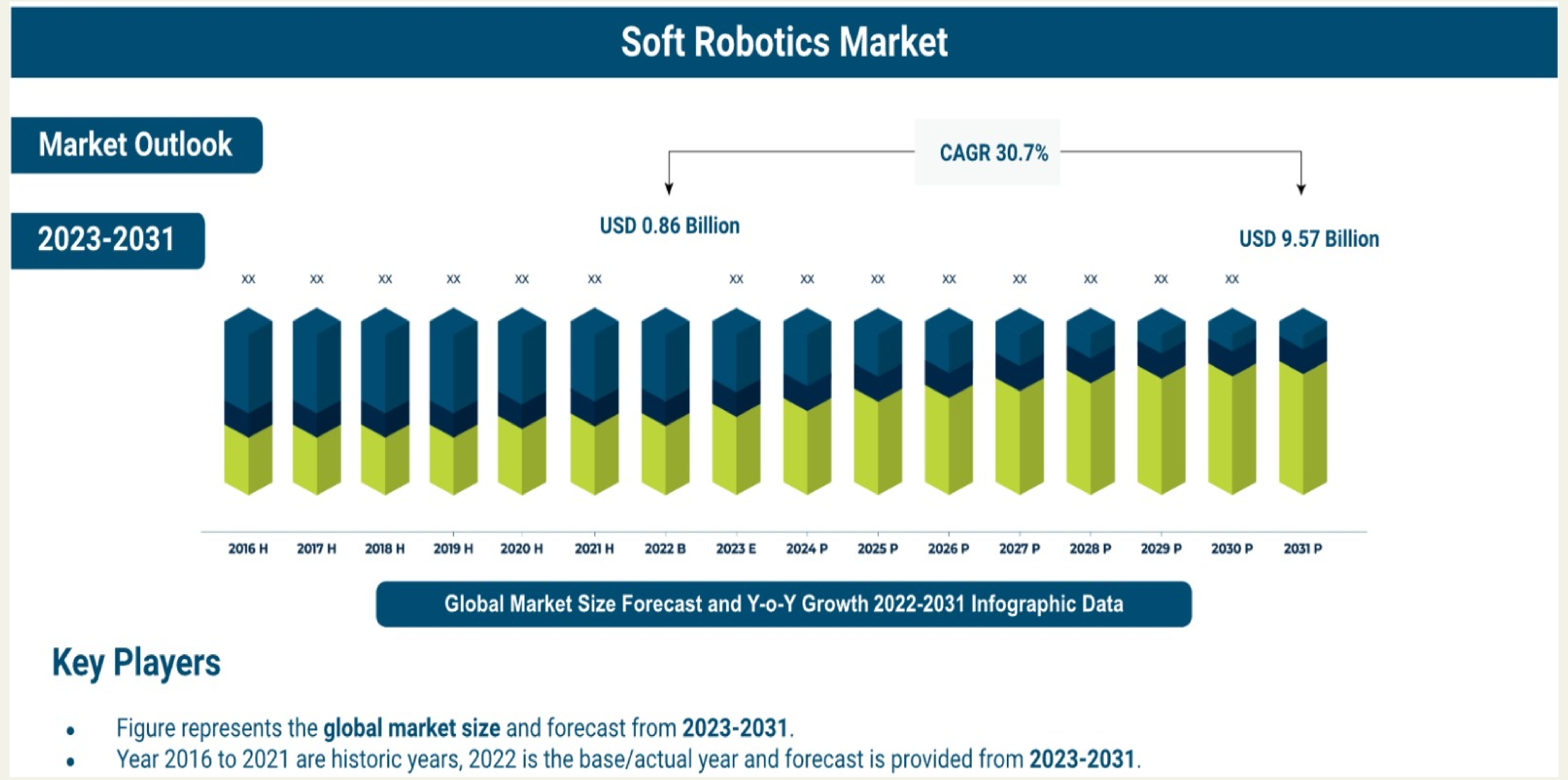
ABSTRACT

Soft robots are seen as the future of robotics due to their flexibility and usage of soft materials, enabling them to work safely alongside humans. Due to its emerging importance, a lot of work is going on in optimising soft robotic designs, like taking inspiration from nature or validating them through modelling techniques to get sustainable and efficient designs. In this project, we aimed to optimise the design parameters of a soft pneumatic actuator using finite element methods. Our goal was to achieve maximum bending at specific pressures while minimising stress concentrations. Additionally, we explored alternative designs to enhance efficiency within soft robotics.

INTRODUCTION



Soft robotics in the form of actuators and grippers have been increasingly used in industries worldwide, and their usage will increase. According to the **2023 Robotics Manufacturing Status Report**, soft actuators and grippers expect a compound annual growth rate of 35.1 per cent between 2022 and 2027, with biomedicine, food, and agriculture set to benefit.



Source: Growth Market Report Analysis

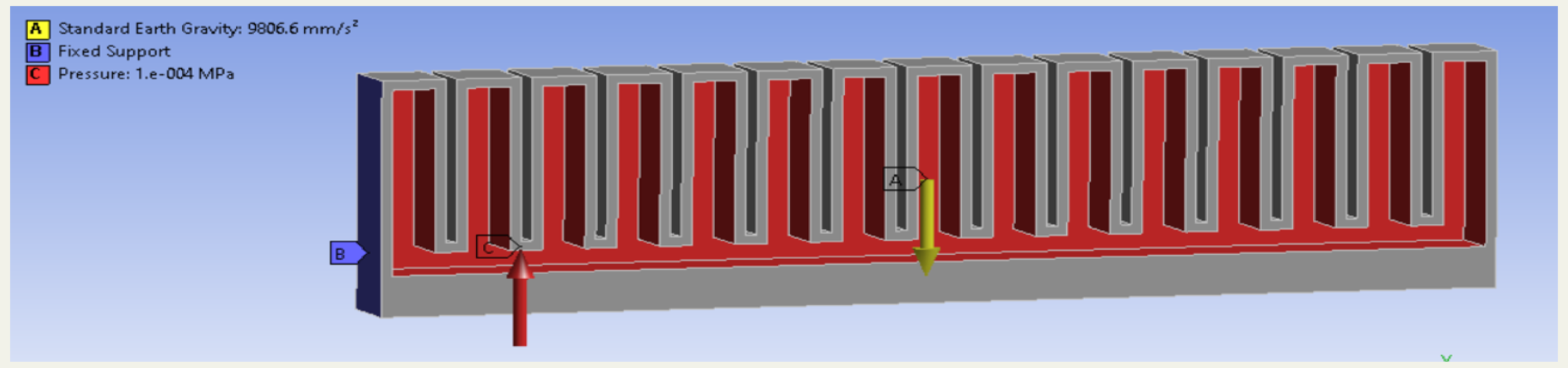
METHOD

We have used FEM as it can accommodate significant deformations and material nonlinearities within Soft Pneumatic Actuators. The following steps were followed in the modelling of the Pneunet Bending Actauator in Ansys:-

1. **Material assignment** - Yeoh 3rd order model and its parameters for Silicon material were chosen for the material assignment. The Yeoh model is chosen because it only needs a small amount of experimental data to get reasonable numerical results. It can also describe a wide range of deformation.

2. **Meshing parameters** - A global element size of 1 to 2 mm is ideal for modelling using the Multizone or Hex Dominant methods for body sizing. The multizone method gave better element quality than Hex Dominant mesh while being more computationally efficient. I have used symmetry to reduce the number of nodes.

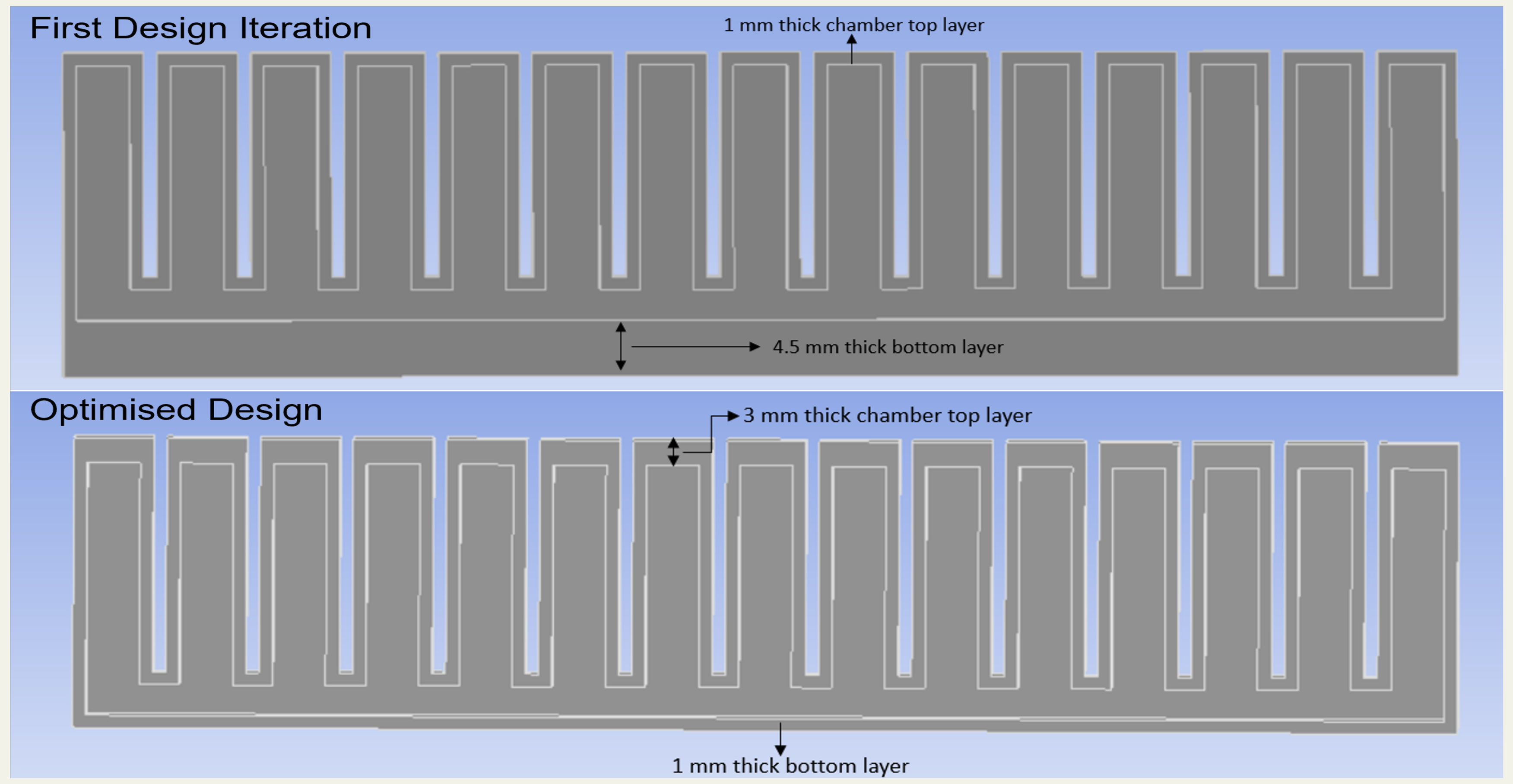
3. **Loads and boundary conditions** - The load applied is of internal pressure of 1 KPa in tabular form. This pressure is applied slowly with 0.1 KPa in each time step. Other than this, standard earth gravity has been applied while one end is fixed as a boundary condition. For better convergence of results, I have used neqit,50, which increased the number of iterations per substep.



4. **Optimization** - Optimization is done based on the relation between the design parameters and the curvature of the Pneunet Bending Actuator (k)-

$$k = \frac{-6(1-\gamma^2)PH^2c}{Et^3x}$$

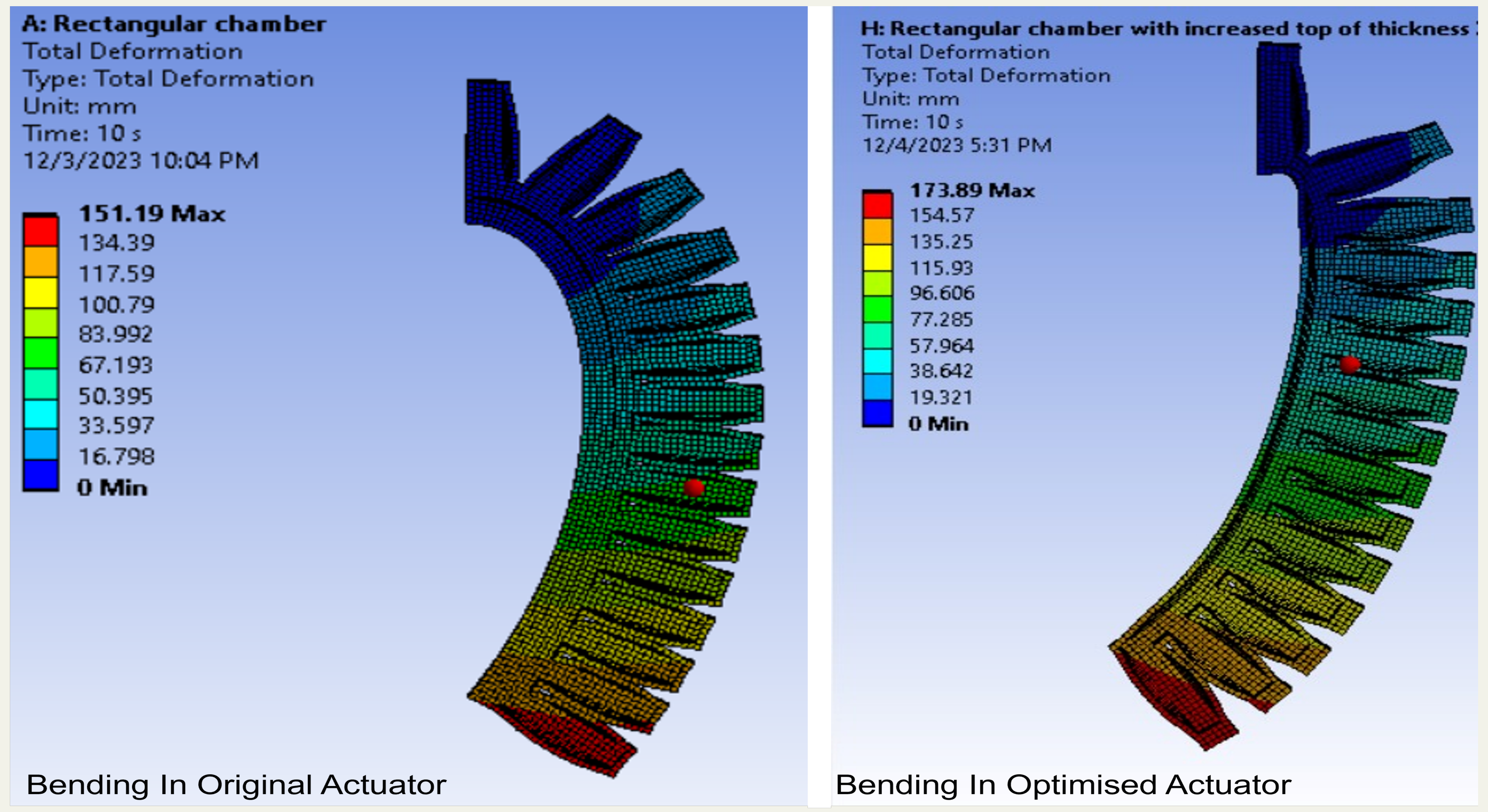
We have varied the thickness t of the bottom restraining layer and height H of the chamber in order to increase the curvature of the pneumatic soft actuator.



RESULTS AND CONCLUSION

The following table compares the initial design of the Pneunet Bending Actuator and the optimised one.

	Max Equivalent Stress (MPa)	Equivalent Strain	Max Total Deformation (mm)
Initial actuator design	0.2786	0.4936	151.19
Optimised actuator design	0.2916	0.4976	173.89



ALTERNATIVE DESIGNS

We can modify the design to act like a claw-shaped soft pneumatic actuator by changing the initial pressure position. Other designs for bending variation can also be explored.