MIN-291 Engineering Analysis and Design

Project Report

Analysis of a 1D viscoelastic bar under axial load

Submitted to – Prof. M.M.Joglekar

Group members

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Abstract-

A material is usually thought of as just a solid or just a liquid but there are some materials which may have both properties to some extent, we call it viscoelasticity.

Purely elastic material stores all the energy during loading and returns it during unloading so there is no energy loss whereas a purely viscous material does not return any of the energy during loading therefore all the energy is loss but viscoelastic materials dissipate energy (Damping) when subjected to mechanical vibrations, making them ideal for damping applications in structures like buildings, bridges, and vehicles.

Viscoelastic materials have been used in a number of different applications including as a buffer under heavy loads to prevent or reduce the damage that can be seen from moving those items. It is very crucial in biomechanics and also used in seismic dampers to absorb and dissipate energy during earthquakes.

Viscoelastic materials also help to deal with the concept of creep which is the tendency of otherwise solid materials to move or to deform with certain stresses or properties.

Introduction-

Viscoelastic materials exhibit a combination of viscous and elastic behavior, are prevalent in a wide range of engineering and scientific applications. Understanding their mechanical responses to various loading conditions is crucial for designing reliable structure and materials.

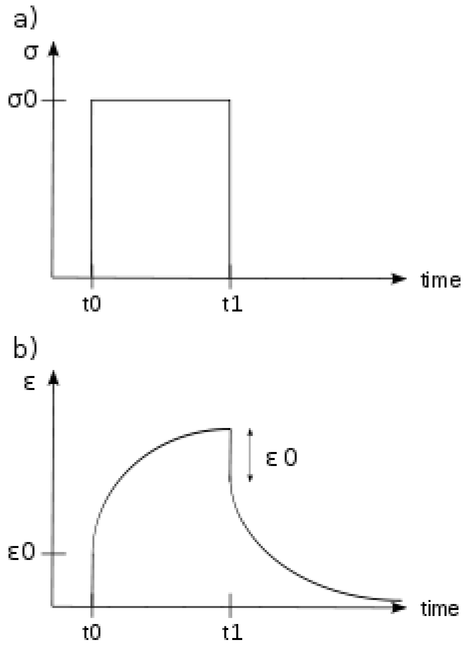
Viscoelastic materials show 3 properties:

1. *Hysteresis:* Viscoelastic substance dissipates energy when a load is applied, then removed.
2. *Creep:* time dependent strain under constant stress
3. *Stress relaxation:* decrease in stress under constant strain.

Linear viscoelasticity is when the function is separable in both creep response and load. The material's viscoelastic properties, including creep and relaxation, are considered in the context of linear viscoelasticity.

The study utilizes mathematical models and numerical simulations to investigate the time-dependent deformation and stress distribution in the bar.

When subjected to a step constant stress, viscoelastic materials experience a time-dependent increase in strain. This phenomenon is known as viscoelastic creep.



a) Applied stress and b) induced strain as functions of time over a short period for a viscoelastic material.

In our project, team has done the analysis of a 1D viscoelastic bar under an axial load and observed the total deformation on bar, total deformation graph, graph of force applied and graph showing stress variations.

ANSYS:

Analysis is the process of analyzing the components by applying load, temperature, pressure etc. and obtaining the values such as stresses, deformation, safety factor etc. in order to determine the safety of the component when done in practice. These Analysis give optimum results of safety of components and minimize the chances of failure. Under this project we have analyzed the 1D viscoelastic bar under axial load using Ansys 2022-R2.

A viscoelastic material is selected for the analysis with the properties shown here.

Properties of Outline Row 4: ViscoElastic Material

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	2402.8	kg m^-3		
4	Isotropic Elasticity				
5	Derive from	Young's ...			
6	Young's Modulus	5E+06	psi		
7	Poisson's Ratio	0.2			
8	Bulk Modulus	1.9152E+10	Pa		
9	Shear Modulus	1.4364E+10	Pa		
10	Prony Shear Relaxation	Tabular			
11	Number of Terms	3			
12	Relative Moduli(i): Scale	1			
13	Relative Moduli(i): Offset	0			
14	Relaxation Time(i): Scale	1			
15	Relaxation Time(i): Offset	0	s		

Analysis of bar:

The analysis is done in three cases

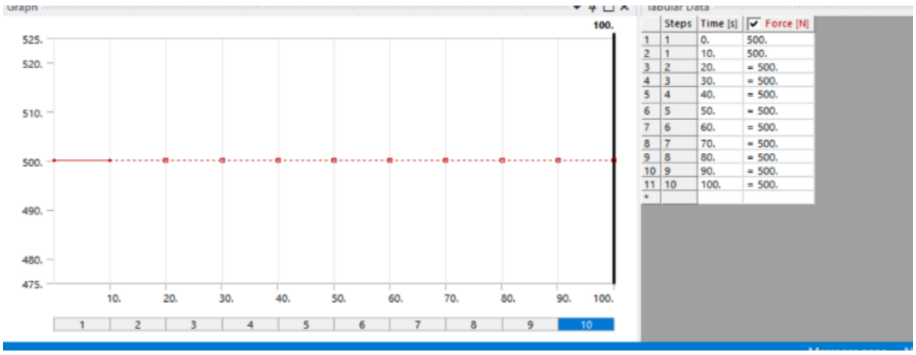
1. ## Creep analysis

   The Bar is fixed at one end and a constant compressive load of 500N Is applied for 100 seconds at the other end

- ### Force distribution graph

Force: 500N

Time: 100s



- ### Direct stress

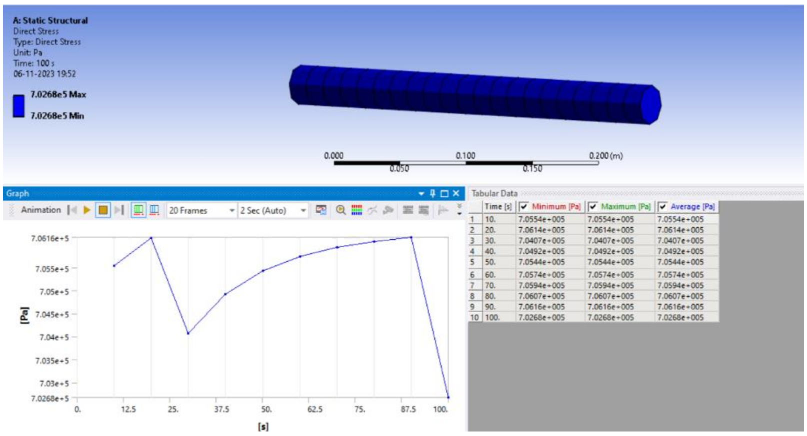
Type: direct stress

Unit: Pascal

Time: 100s

Maximum stress: 7.0268 X 10^5 (7.0268e5)

Minimum stress: 7.0268 X 10^5 (7.0268e5)



- ## <u>Total deformation</u>

Type: Total deformation

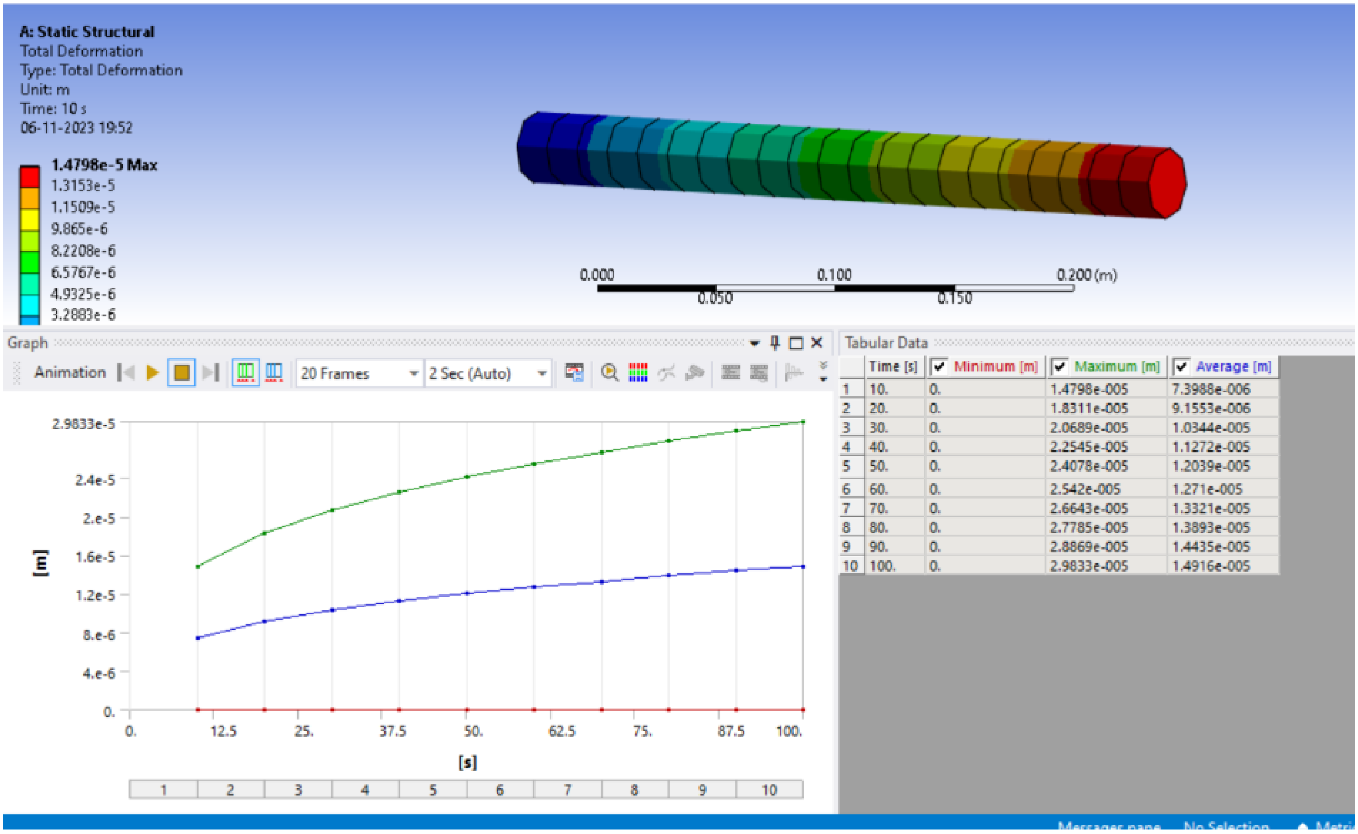
Unit: meter

Time: 10s

Maximum deformation: 1.4798e-005

Average deformation:7.3988e-006

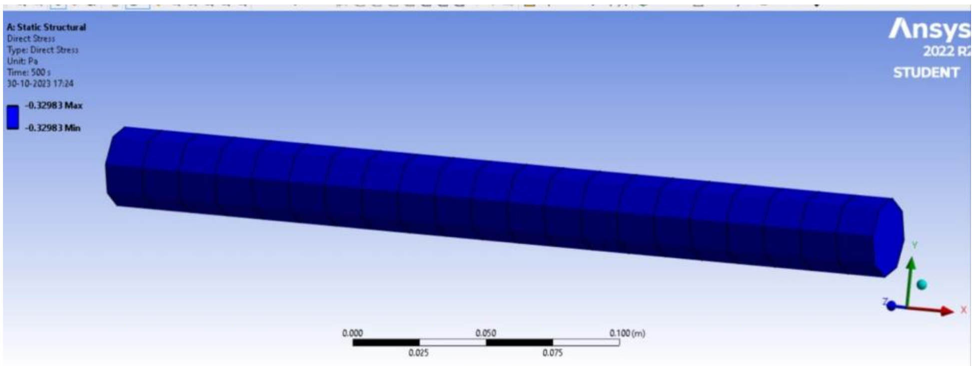
Minimum deformation:0



2. General Analysis

Fixed Support At One End And Variable Force At Other End.

Uniaxial time varying load is applied on the bar which linearly increases for first 100 sec then linearly decreases for another 300 sec till it vanishes then stays 0 for another 100 sec.



- **Stress**

Type: direct stress

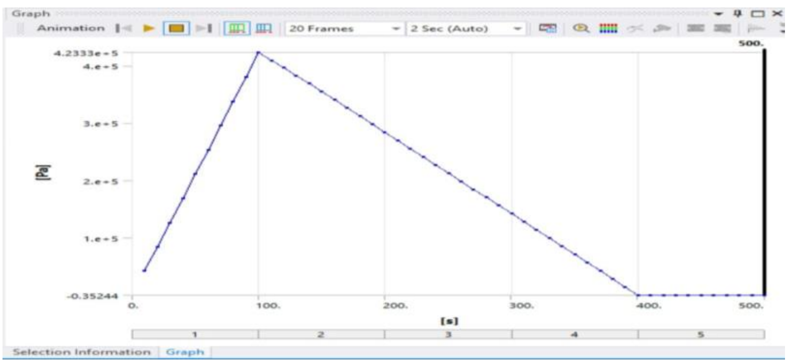
Unit: Pascal

Time: 500s

Maximum stress: -0.32983

Minimum stress: -0.32983

- **Stress variation graph**



- **Deformation**

  Type: total deformation

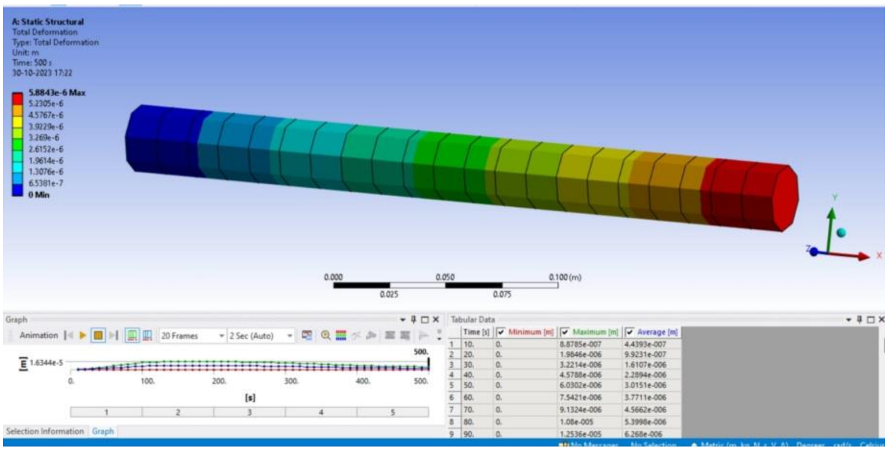
  Unit: meter

  Time: 500s

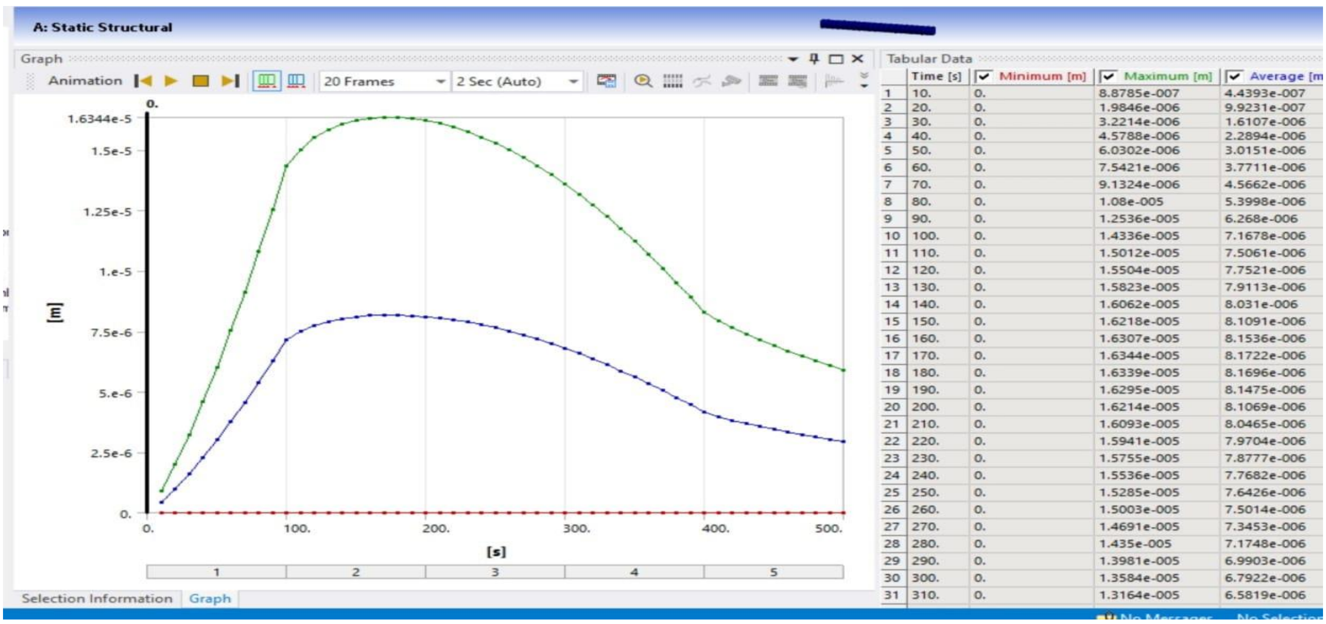
  Maximum deformation: 8.8785e-007

  Average deformation: 4.4393e-007

  Minimum deformation: 0



- **Deformation graph**



	Time [s]	Minimum [m]	Maximum [m]	Average [m
1	10.	0.	8.8785e-007	4.4393e-007
2	20.	0.	1.9846e-006	9.9231e-007
3	30.	0.	3.2214e-006	1.6107e-006
4	40.	0.	4.5788e-006	2.2894e-006
5	50.	0.	6.0302e-006	3.0151e-006
6	60.	0.	7.5421e-006	3.7711e-006
7	70.	0.	9.1324e-006	4.5662e-006
8	80.	0.	1.08e-005	5.3998e-006
9	90.	0.	1.2536e-005	6.268e-006
10	100.	0.	1.4336e-005	7.1678e-006
11	110.	0.	1.5012e-005	7.5061e-006
12	120.	0.	1.5504e-005	7.7521e-006
13	130.	0.	1.5823e-005	7.9113e-006
14	140.	0.	1.6062e-005	8.031e-006
15	150.	0.	1.6218e-005	8.1091e-006
16	160.	0.	1.6307e-005	8.1536e-006
17	170.	0.	1.6344e-005	8.1722e-006
18	180.	0.	1.6339e-005	8.1696e-006
19	190.	0.	1.6295e-005	8.1475e-006
20	200.	0.	1.6214e-005	8.1069e-006
21	210.	0.	1.6093e-005	8.0465e-006
22	220.	0.	1.5941e-005	7.9704e-006
23	230.	0.	1.5755e-005	7.8777e-006
24	240.	0.	1.5536e-005	7.7682e-006
25	250.	0.	1.5285e-005	7.6426e-006
26	260.	0.	1.5003e-005	7.5014e-006
27	270.	0.	1.4691e-005	7.3453e-006
28	280.	0.	1.435e-005	7.1748e-006
29	290.	0.	1.3981e-005	6.9903e-006
30	300.	0.	1.3584e-005	6.7922e-006
31	310.	0.	1.3164e-005	6.5819e-006

3. Stress relaxation analysis

Fixed Support At One End And A Displacement Of 30mm At The Other End

- ## Total deformation

Type: total deformation

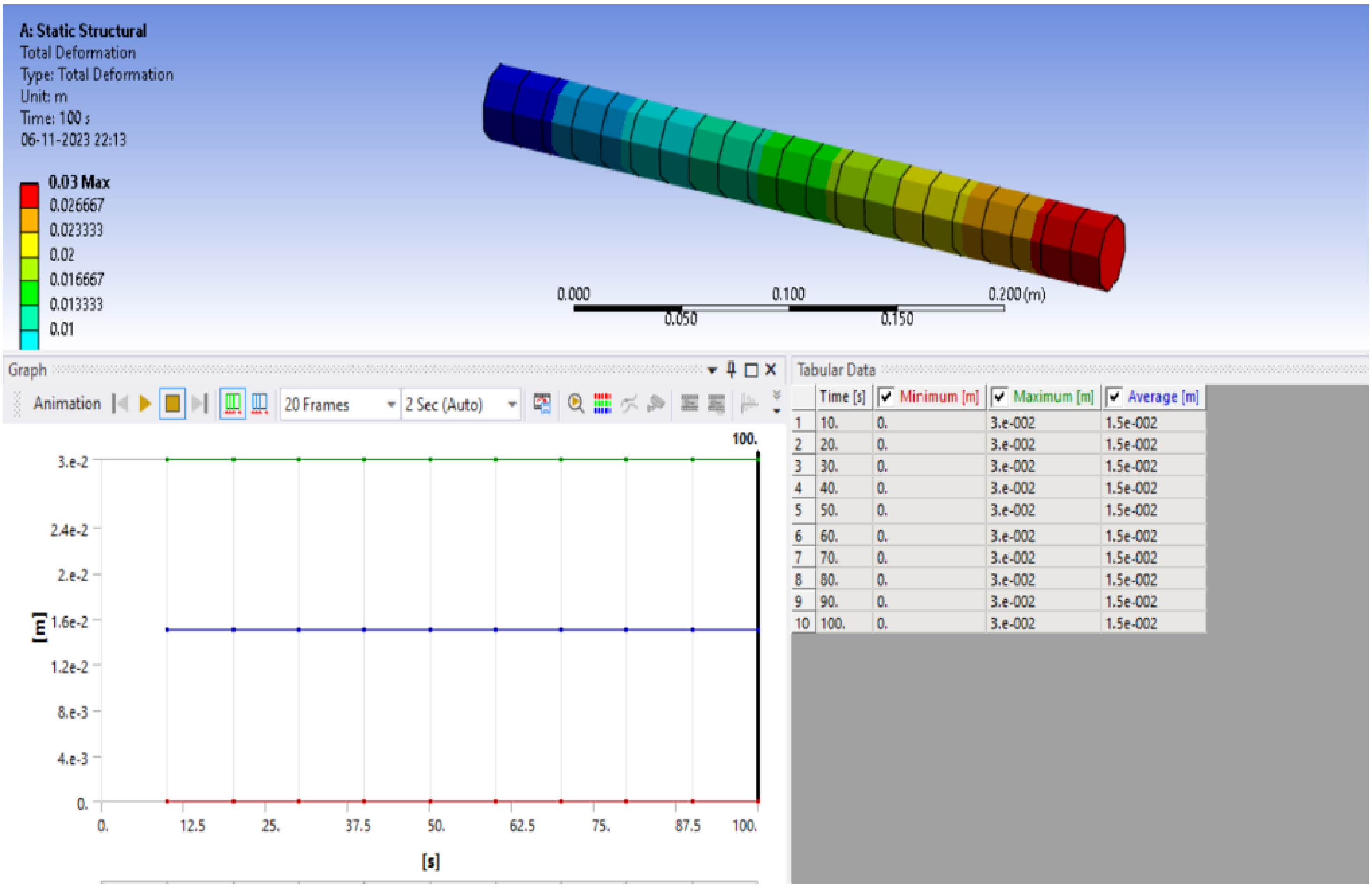
Unit: meter

Time: 100s

Maximum deformation: 3.e-002

Average deformation: 1.5e-002

Minimum deformation: 0



	Time [s]	Minimum [m]	Maximum [m]	Average [m]
1	10.	0.	3.e-002	1.5e-002
2	20.	0.	3.e-002	1.5e-002
3	30.	0.	3.e-002	1.5e-002
4	40.	0.	3.e-002	1.5e-002
5	50.	0.	3.e-002	1.5e-002
6	60.	0.	3.e-002	1.5e-002
7	70.	0.	3.e-002	1.5e-002
8	80.	0.	3.e-002	1.5e-002
9	90.	0.	3.e-002	1.5e-002
10	100.	0.	3.e-002	1.5e-002

- **Stress**

  Stress decreases with the time which is called stress relaxation

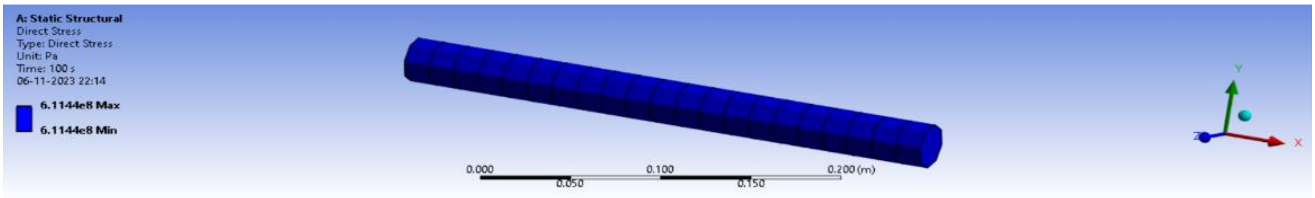
  Type: direct stress

  Unit: pascal

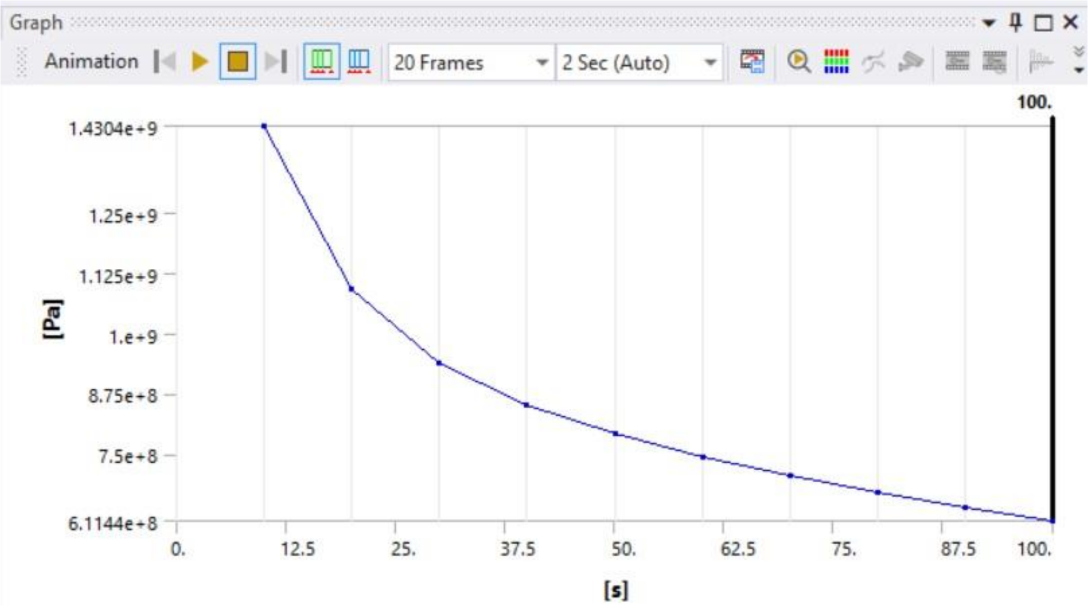
  Time :100s

  Maximum stress: 6.1144e8

  Minimum stress: 6.1144e8



- **Stress time graph**



Conclusion

Viscoelastic properties of a material can significantly affect its mechanical behavior

Under axial load in several ways:

1. Time dependent deformation
2. The stress strain curve for viscoelastic material is not purely linear like in elastic materials.
3. Viscoelastic material dissipate energy as heat due to internal friction.
4. When viscoelastic material undergoes cyclic loading and unloading, it can exhibit hysteresis in its stress-strain curve, indicating energy loses during the loading and unloading cycles.
5. Because of these properties viscoelastic materials are ideal for many jobs such as dampers, shock absorbers, noise controller etc.

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- https://youtu.be/xCkRwjz5mGY?si=H1_aNGz6vpWcIKpI
- https://youtu.be/EJxJlfAAW2g?si=YLAt9A0dN80X6qoN

Contribution:

Megha Choudhary	• Report • Info about viscoelastic material
Mehul Sharma	• Presentation prepared • Overview of whole project
Mohammad Sabir	• Assisted in report • Info about viscoelastic material
Munnaluru Ruthika	• Anyisis simulation • Overview of project
Muskan	• Assisted in ppt • Assisted in report