

Finite element Analysis of Sandwich structures using Visco-elastic foam cores for Mechanical applications

Presented By

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Sequence of Presentation



- Motivation
- Introduction
- Ansys
- Problem Statement
- Results
- Conclusion

Viscoelastic foams

- are used for vibration attenuation and energy absorption during impact applications. For example, polyurethane foam, XPS foams
- are widely used in aerospace and automotive field due to its light weight and good energy absorption capabilities.

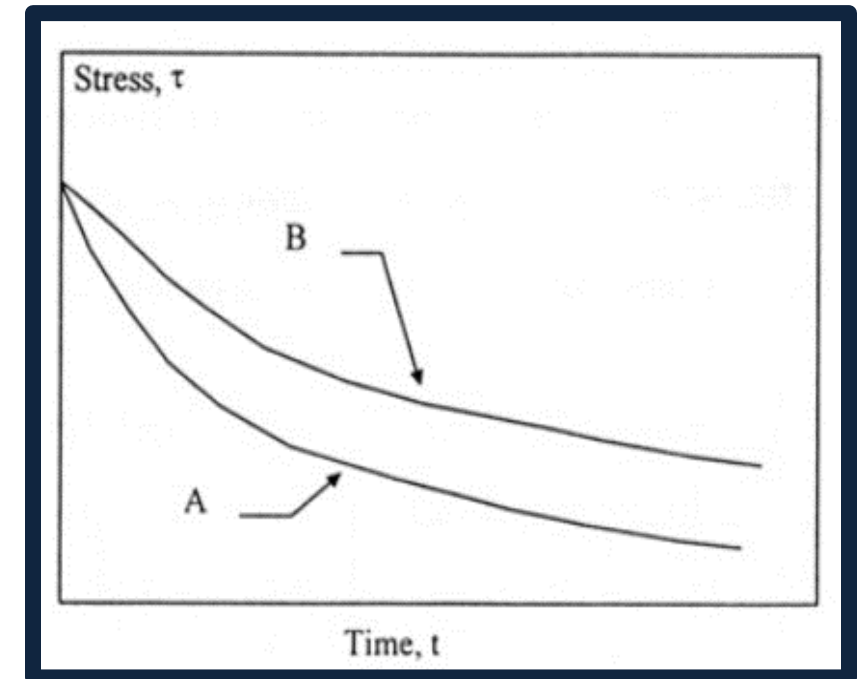
Therefore, it is interesting to analyze these materials from the point of view of vibration attenuation and impact absorption properties.

- Viscoelasticity is the property of the material that exhibits both elastic as well as viscous characteristics while undergoing deformation.
- A viscoelastic material has two components, Elastic component and Viscoelastic component.
- Viscoelastic component is responsible for energy dissipation when the load is applied and then removed, which is called Hysteresis. Hence a viscous material will lose energy through a loading cycle.

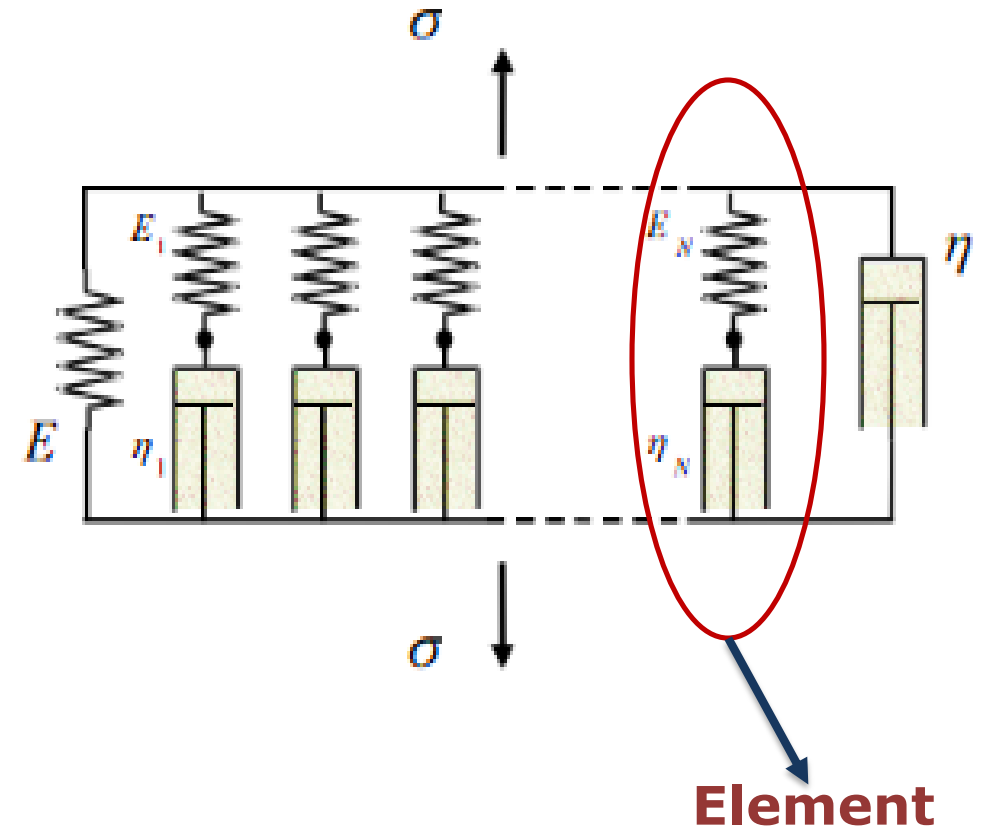
Property of Viscoelastic Materials

Stress Relaxation

When the viscoelastic material is subjected to constant strain, the stresses in the material will relax with the passage of time and at the last, it will attain a steady state value



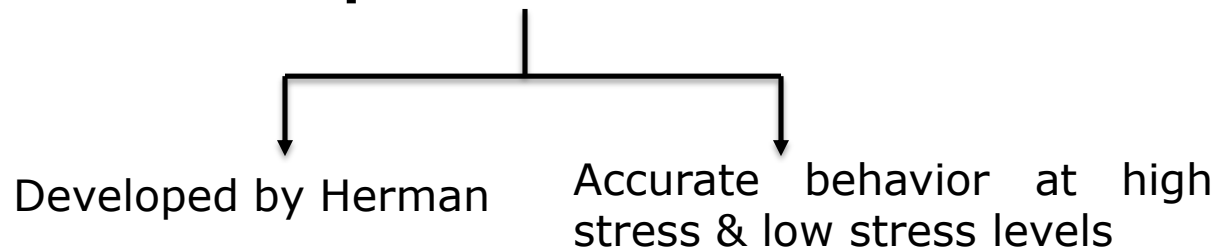
- Maxwell Model
- Kelvin-Voigt Model
- Standard-Linear solid Model
- Burgers Model
- **Generalized Maxwell Model**



Material Models for Foams

Porous materials are extremely effective in attenuating shocks and mitigating impact pressures.

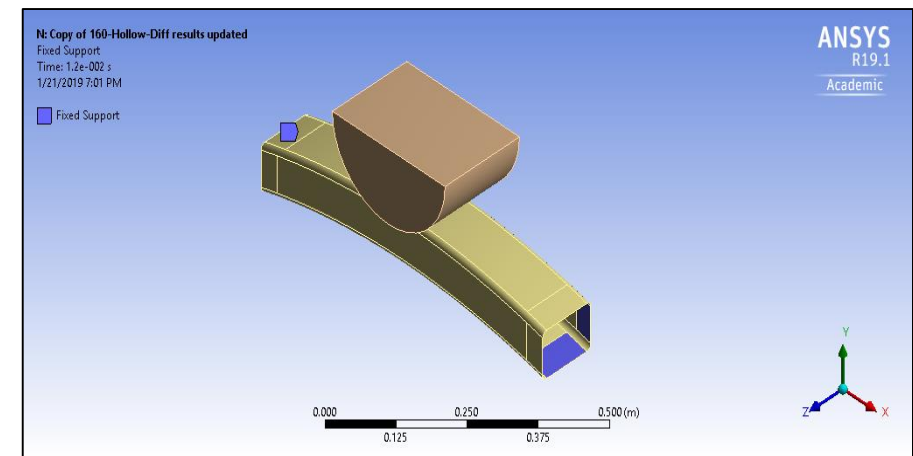
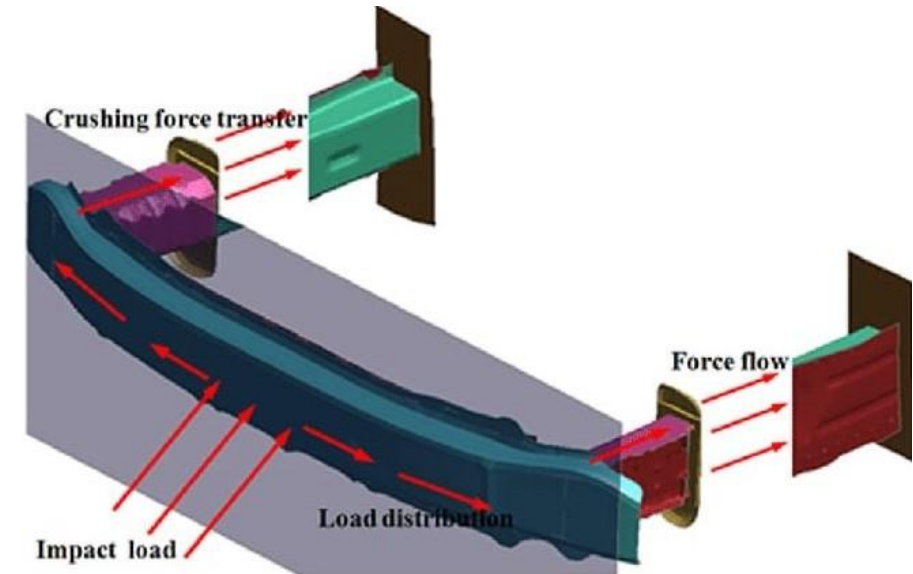
- Crushable Foam
- Compaction EOS linear
- Compaction EOS Non-linear
- **P-alpha EOS**



- Ansys student version 19.1
- Explicit Dynamics

Problem Statement

- To study the behavior of a **curved hollow rectangular beam** similar to the **car front bumper beam** with **fixed-fixed** boundary condition impacted by a rigid body and then compare it with the **Polyurethane foam filled rectangular beam** of **same dimensions and loading conditions**.



Problem Statement

- Two different geometries, densities of PU foam and contact type between PU foam and beam body are considered

Geometry

- Simple hollow beam
- Two-channel hollow beam

Density of PU foam

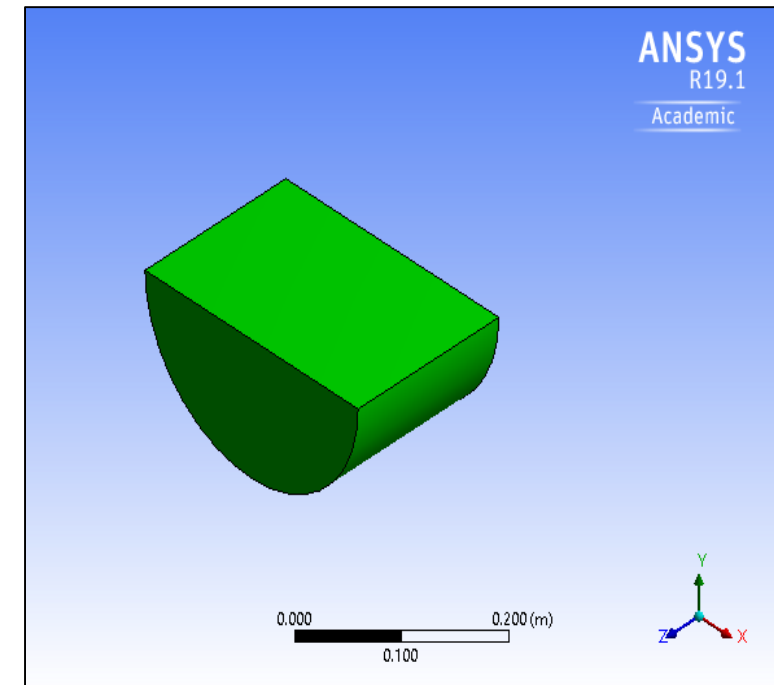
- 40 kg/m³
- 93 kg/m³

Contact type

- bonded
- Non-bonded

Rigid Body (Impactor) Parameters

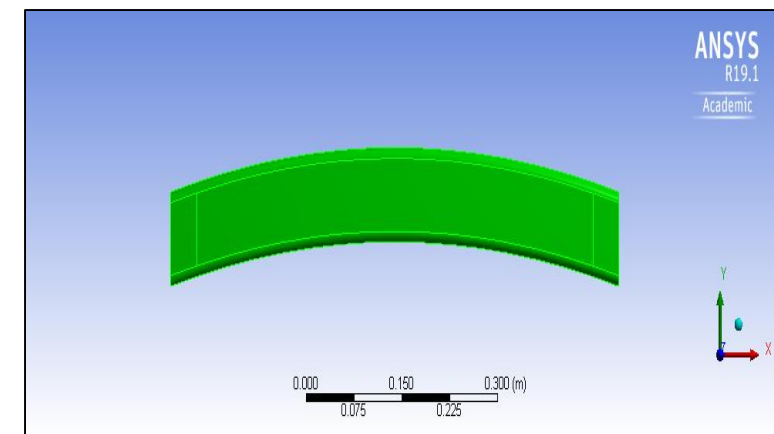
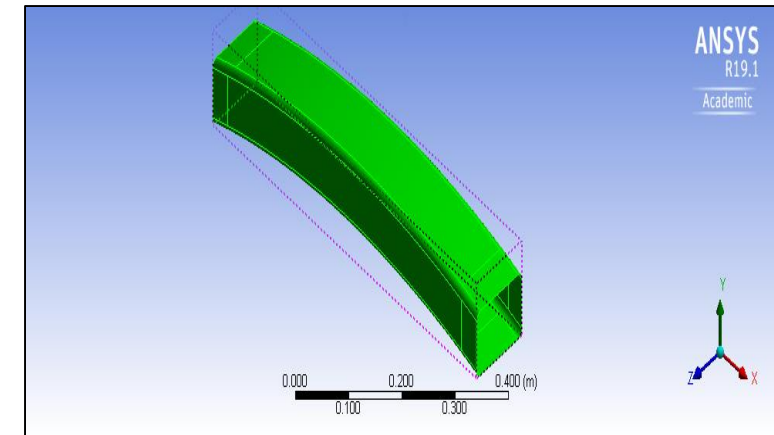
Material	Structural Steel
Type	Rigid
Mass	51kg
Initial Velocity	15 m/s
Diameter	280 mm
Extrude Length	92.5 mm



Beam body Parameters



Material	Structural Steel
Width of X-sec (outer)	121 mm
Height of X-sec (outer)	91 mm
Radius	1480 mm



Different Configurations

**Simple beam PU
Foam 40kg/m³**

	Type	Type	Skin thickness	Weight	
Case 1	Hollow Beam	-	2.13 mm	4.73	-
Case 2	Foam-filled beam	PUF	2mm	4.73	Bonded

**Simple beam PU
Foam 93kg/m³**

	Type	Type	Skin thickness	Weight	
Case 3	Hollow Beam	-	2.3 mm	5.12	-
Case 4	Foam-filled beam	PUF	2mm	5.12	Bonded
Case 5	Foam-filled beam	PUF	2mm	5.12	Non-Bonded
Case 6	Foam-filled beam	PUR	2mm	5.12	Bonded

**Two-channel beam
PU Foam 93kg/m³**

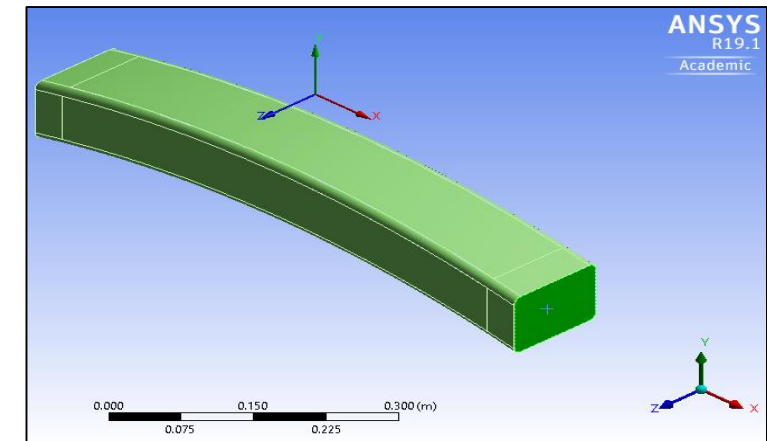
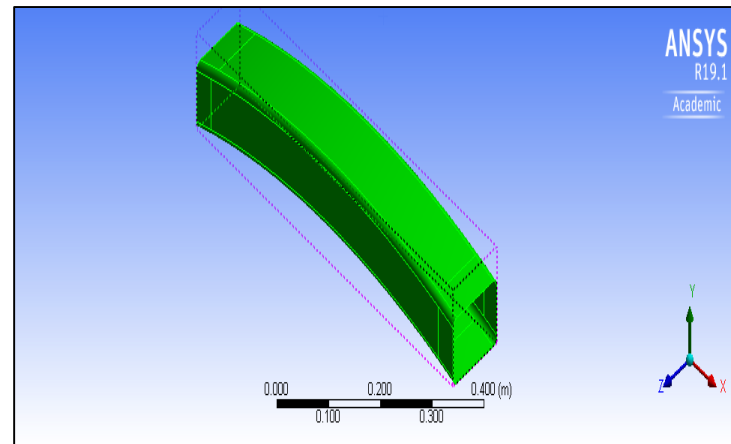
	Type	Type	Skin thickness	Weight	
Case 7	Two-channel hollow beam	-	2.24 mm	6.06	-
Case 8	Two-channel Foam-filled beam	PUF	2mm	6.06	Bonded

Beam body

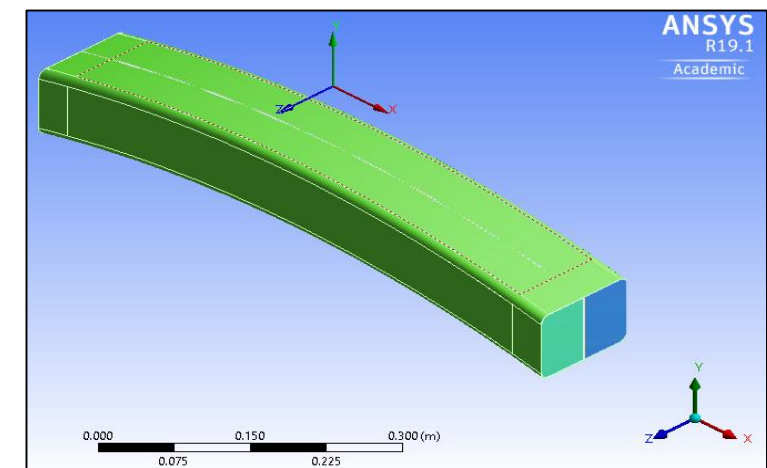
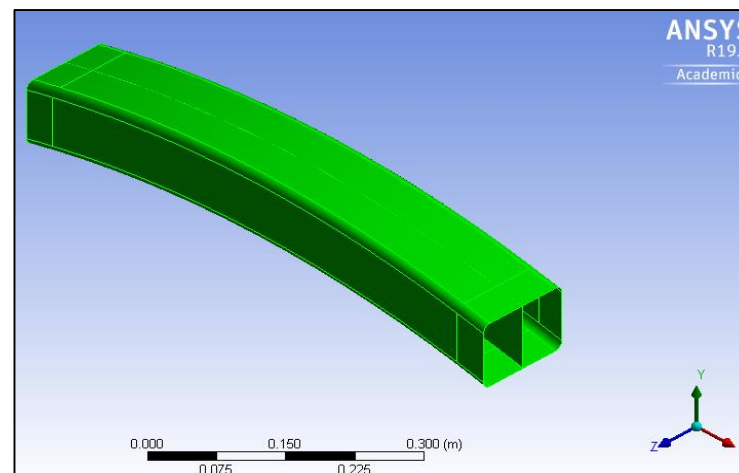


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**Simple hollow and
PU-filled beam**



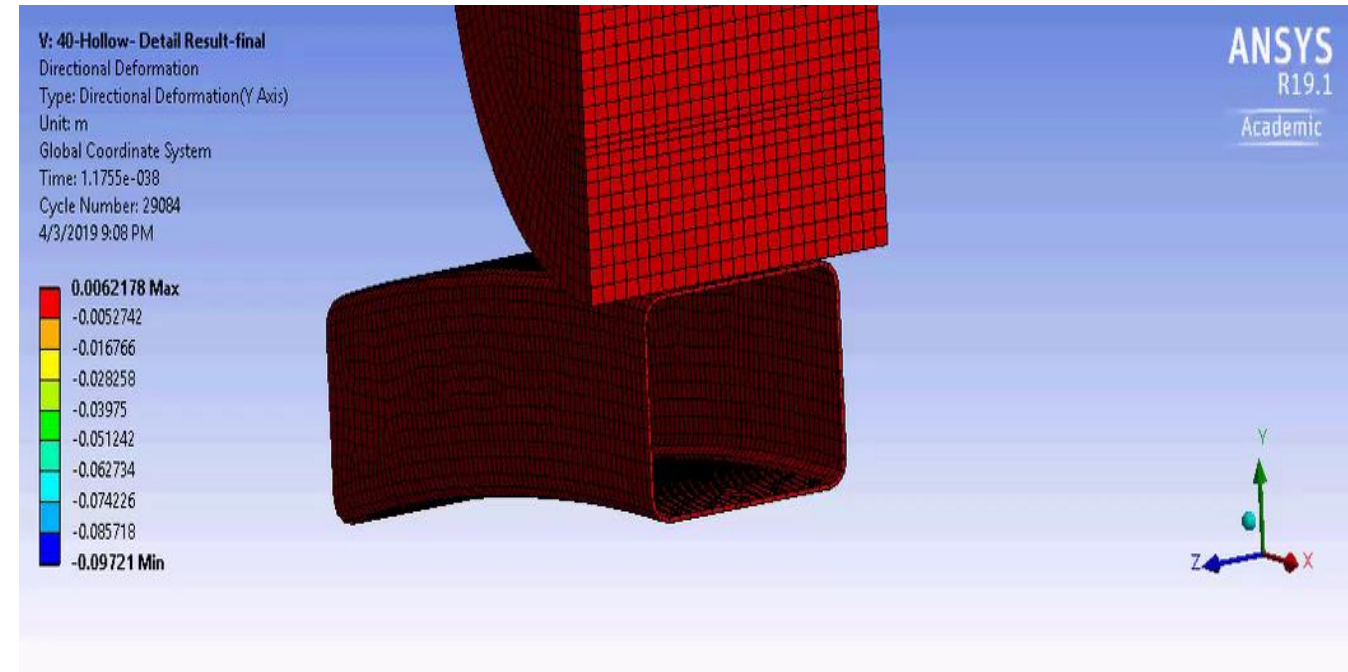
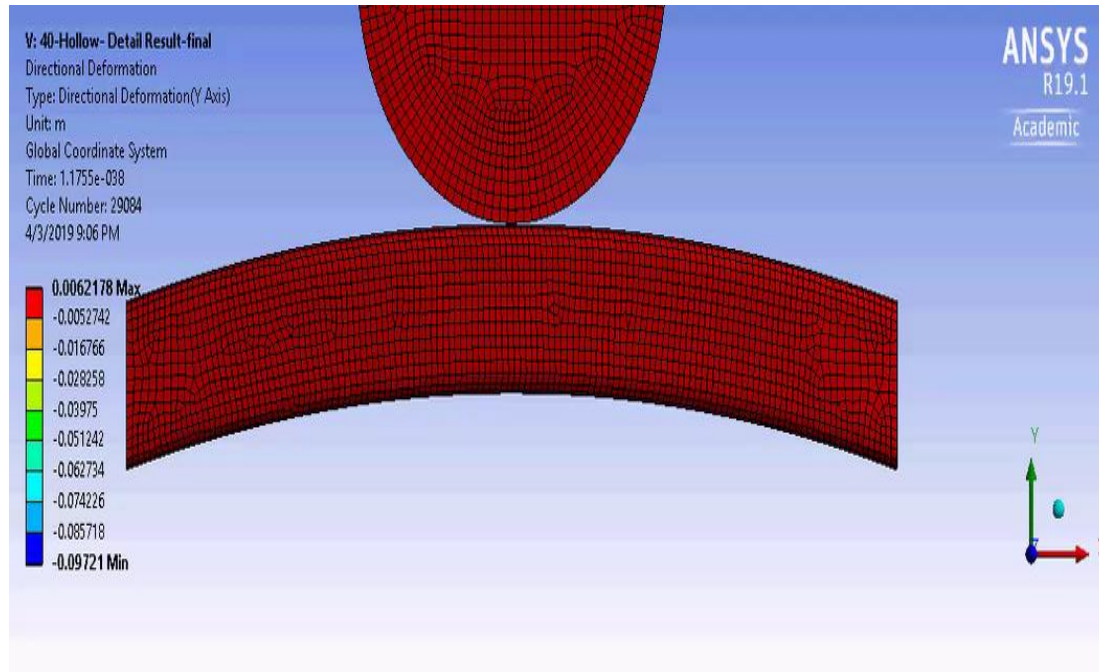
**Two channel Hollow
and PU-filled beam**



Impact Video



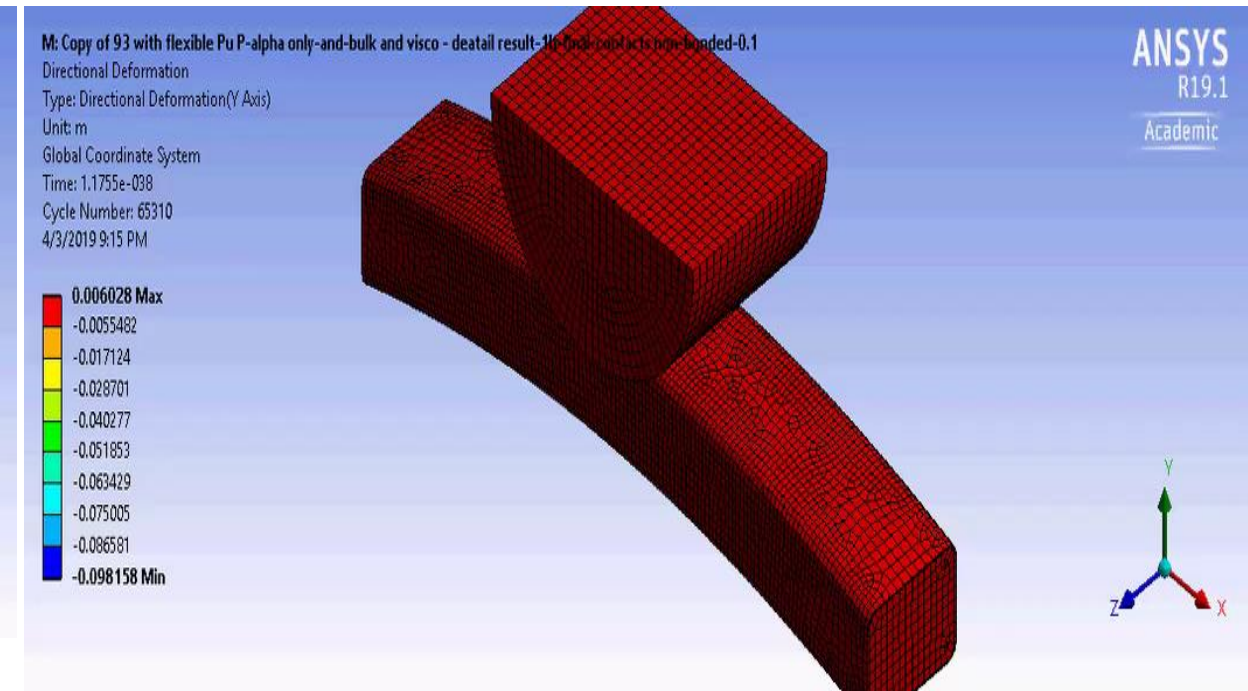
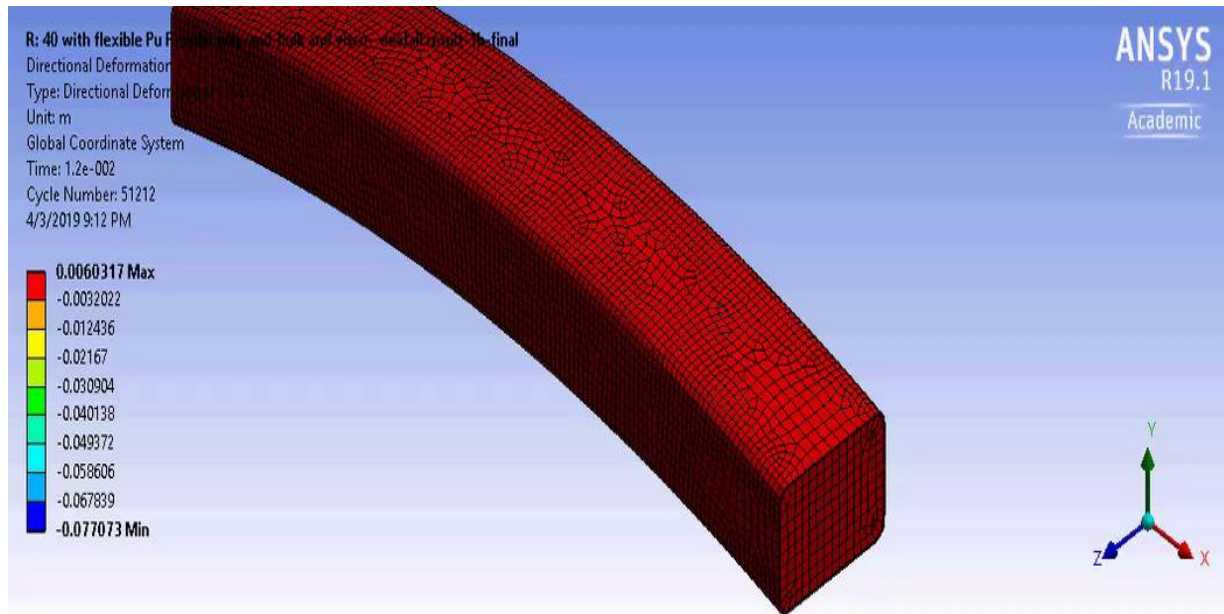
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Impact Video



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Comparison



Hollow Beam

	Geometry	Skin thickness	Weight (kg)
Case 1	Simple Hollow beam	2.13 mm	4.73
Case 3		2.3 mm	5.12
Case 7		2.24mm	6.06

VS



VS



VS



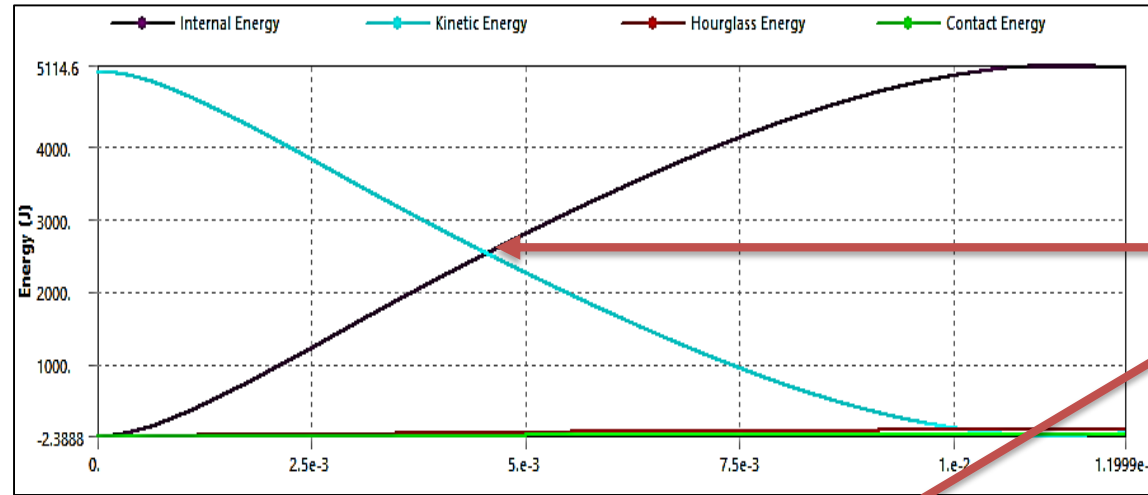
PU sandwich Beam

	Skin thickness	Weight (kg)
Case 2	2 mm	4.73
Case 4		5.12
Case 5		
Case 6		
Case 8		6.06

- i. Energy graph**
- ii. Reaction-force time graph**
- iii. Acceleration-time graph**

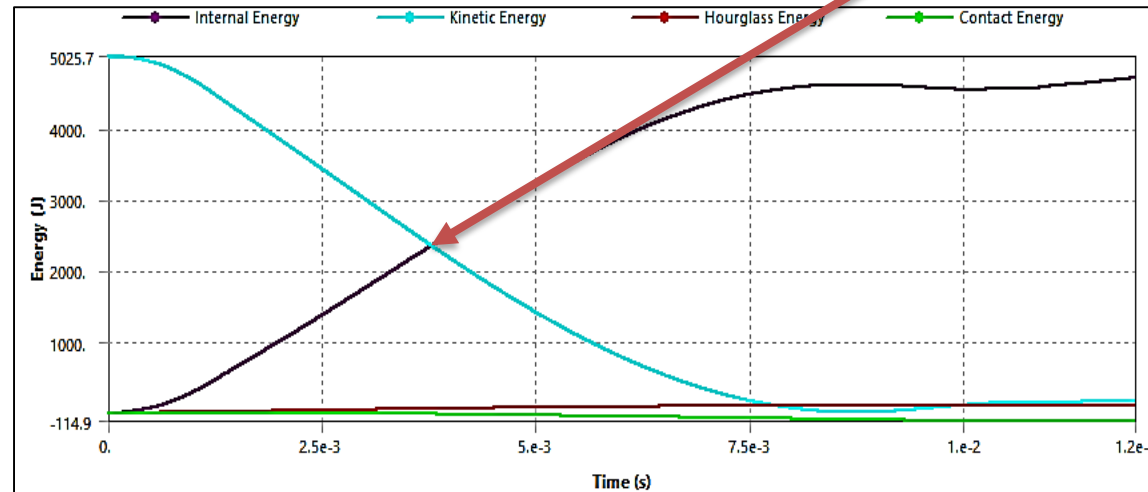
Results - [Energy graph]

Hollow beam (Case 1)



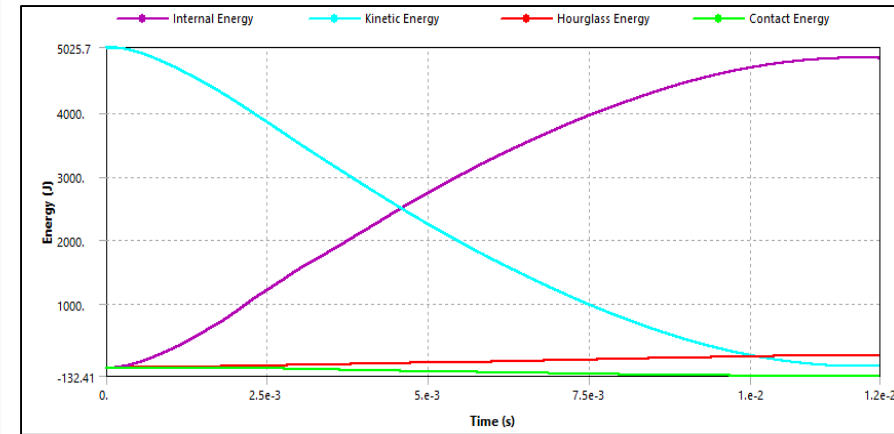
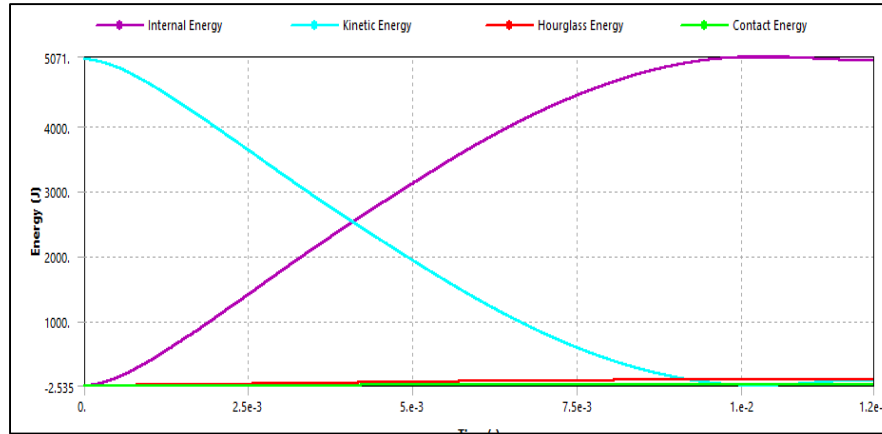
Difference in reduction of energy w.r.t time

PU-filled beam with density 40kg/m³ (Case 2)



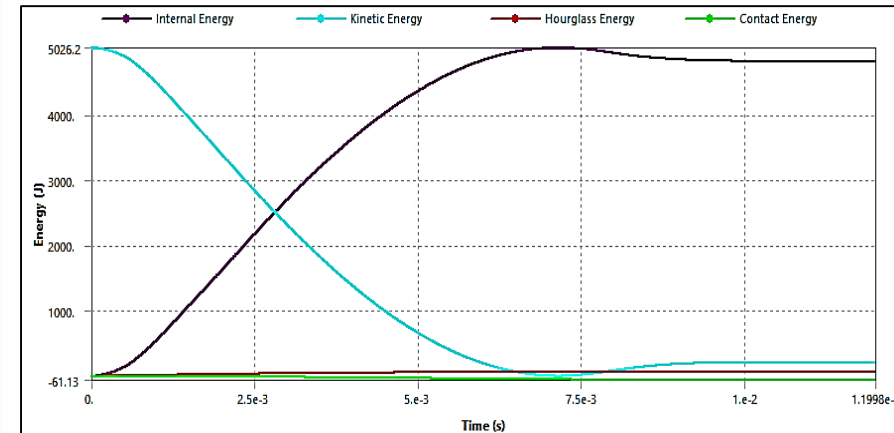
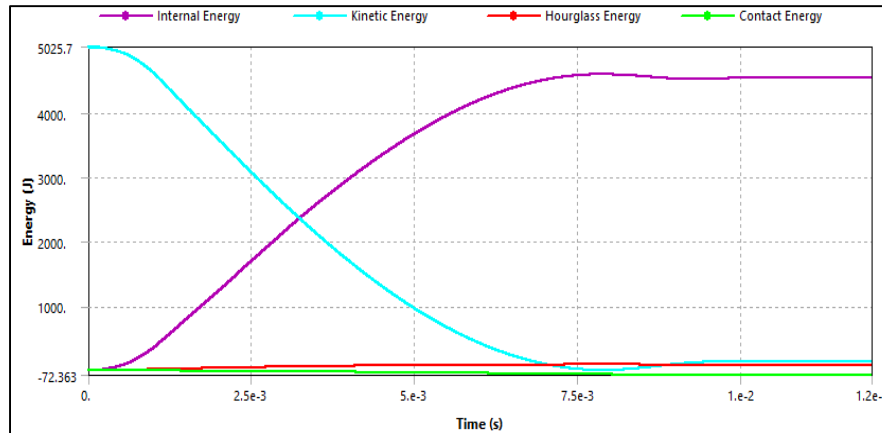
Results - [Energy graph]

Hollow beam
(Case 3)



PU-filled beam
with density
93kg/ m³ (Case
5-non-bonded)

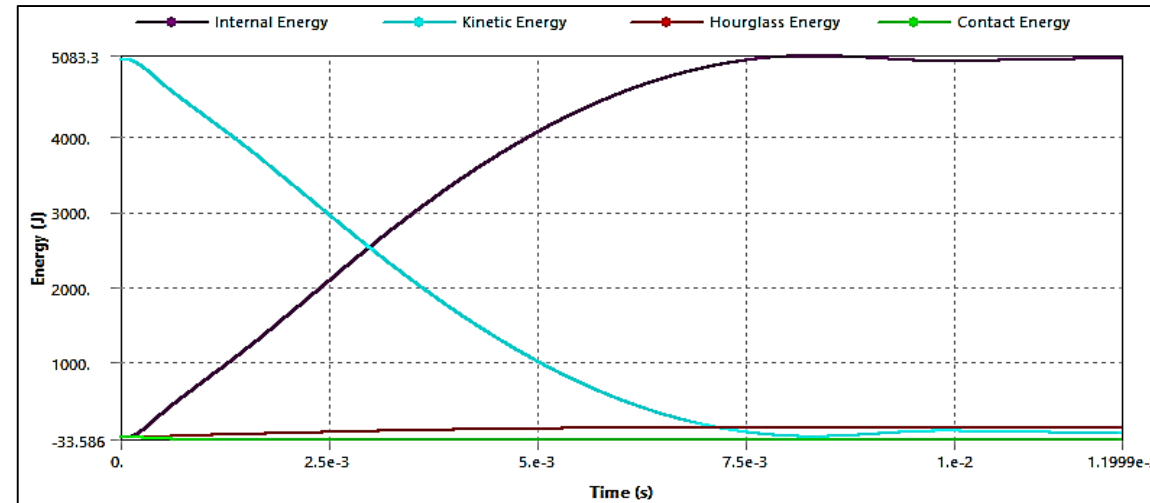
PU-filled beam
with density
93kg/ m³ (Case
4-bonded)



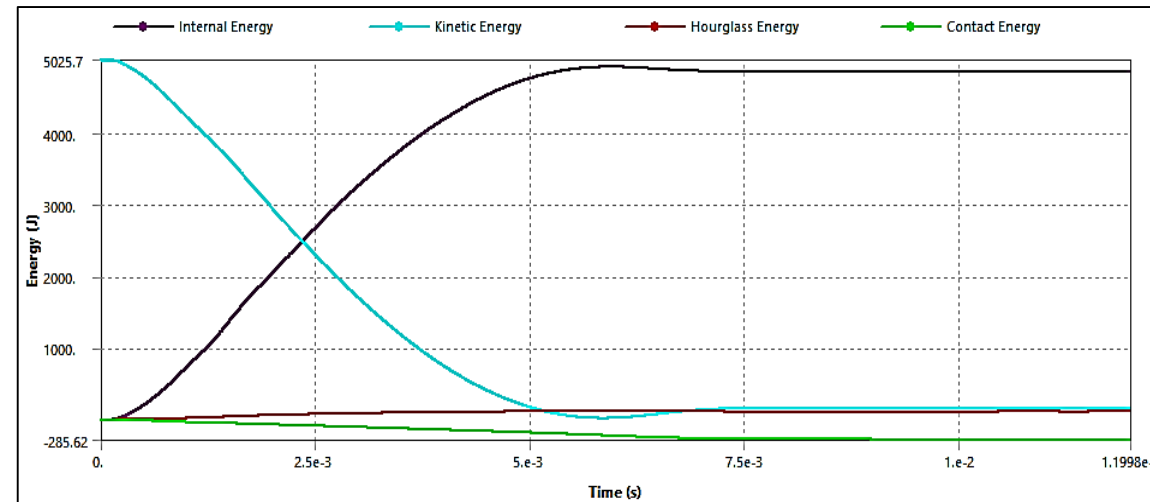
PUR-filled beam
with density
93kg/ m³ (Case
6 bonded)

Results - [Energy graph]

Two Channel Hollow
beam (Case 7)

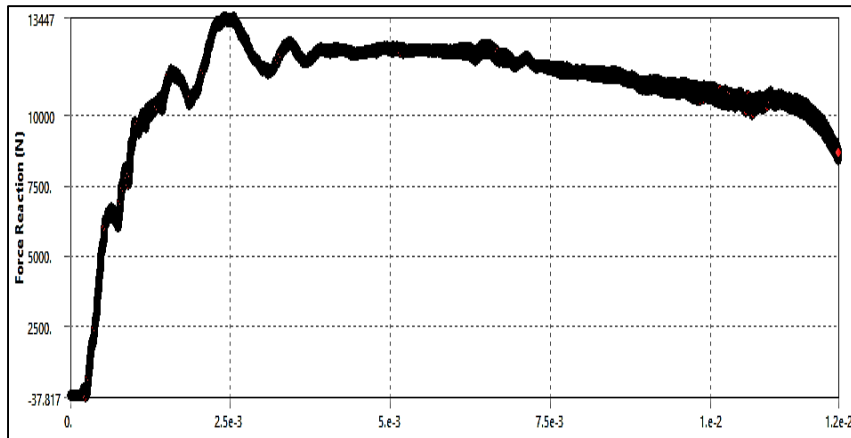


Two channel PU-filled beam with
density 93kg/m³ (Case 8)

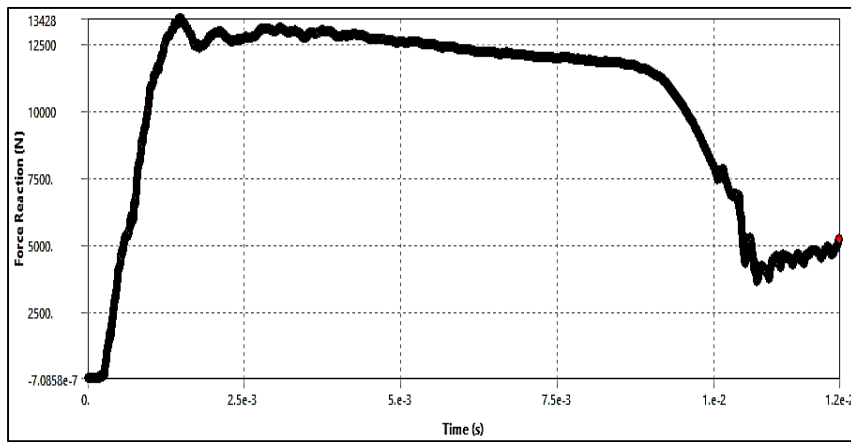


Results – [Reaction force]

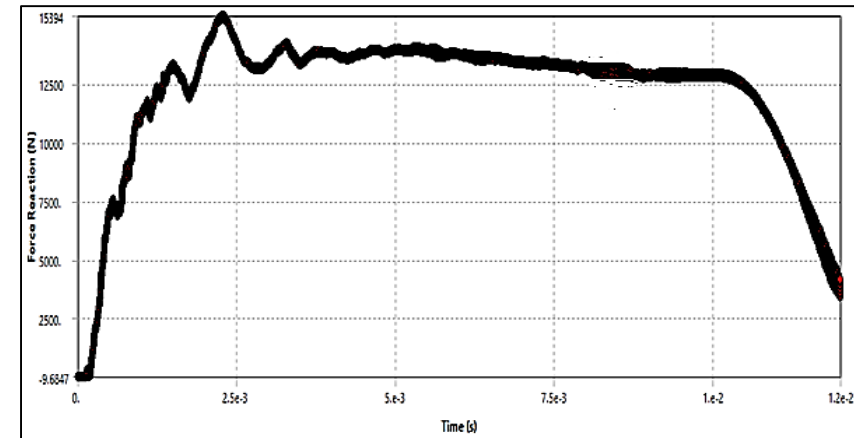
Hollow
beam
(Case 1)



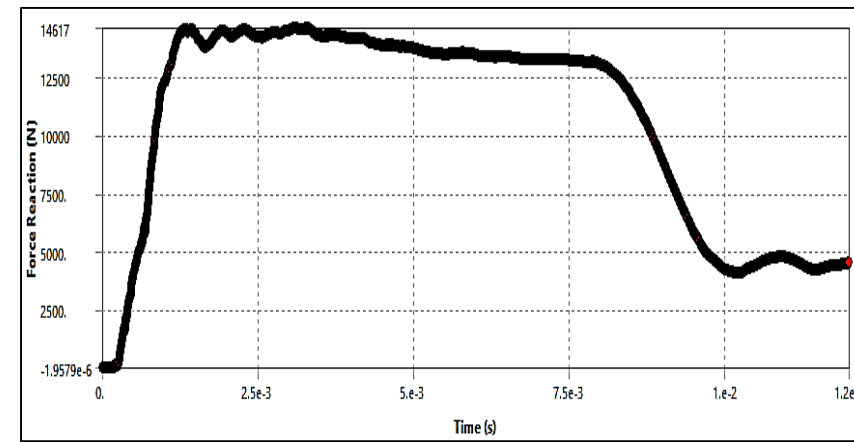
PU-filled
beam with
density
 40kg/m^3
(Case 2)



Hollow
beam
(Case 3)

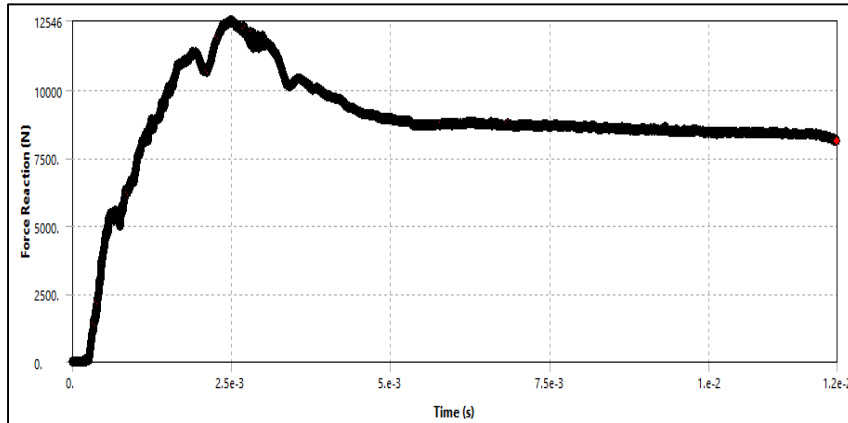


PU-filled
beam with
density
 93kg/m^3
(Case 4)

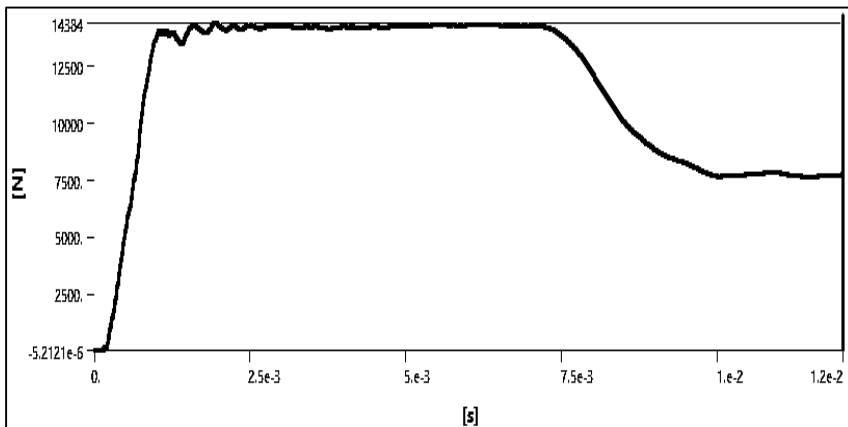


Results – [Reaction force]

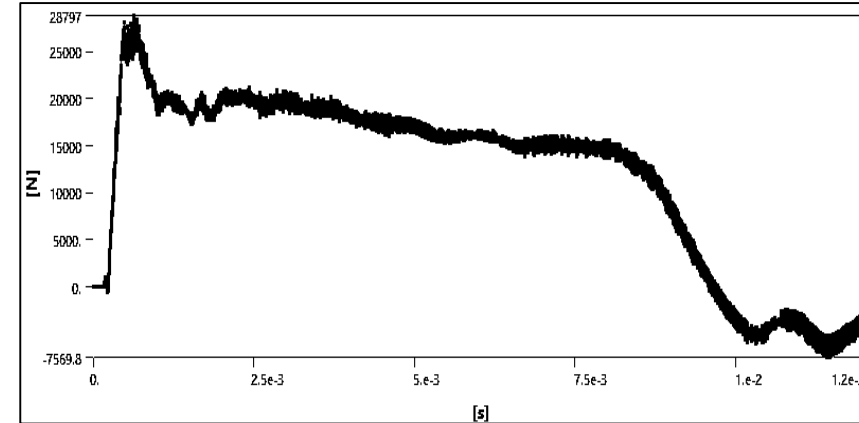
PUF-filled
beam with
density
 93kg/m^3
(Case 5)



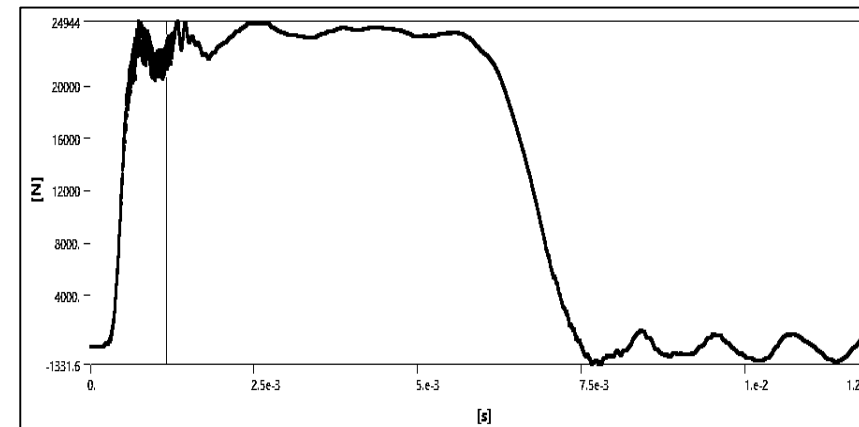
PUR-filled
beam with
density
 93kg/m^3
(Case 6)



Two-channel
Hollow beam
(Case 7)

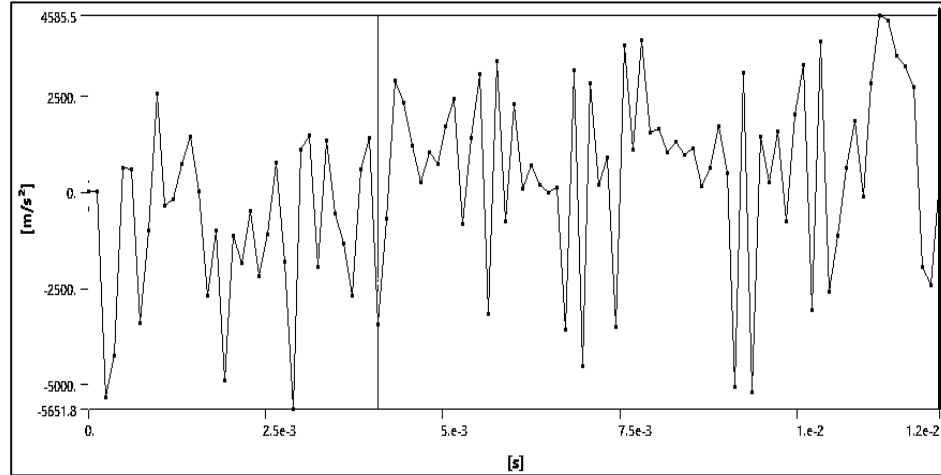


Two-channel
PU-filled
beam with
density
 93kg/m^3
(Case 8)

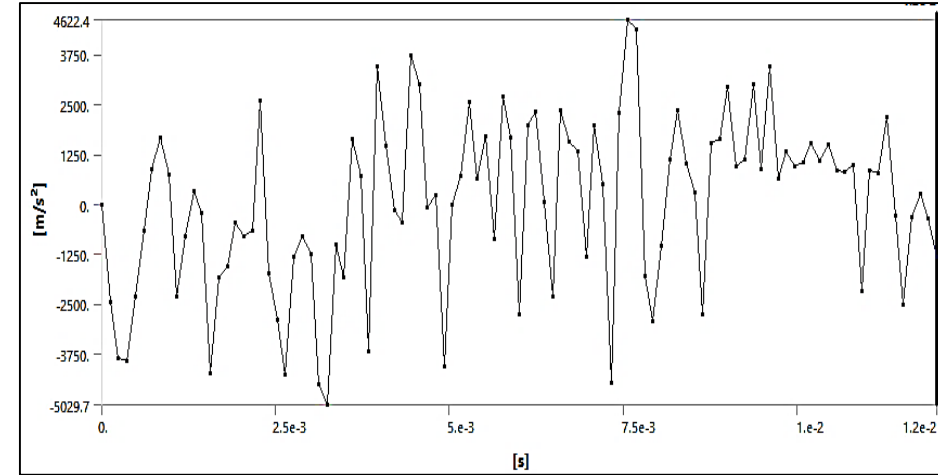


Results – [Acceleration-time]

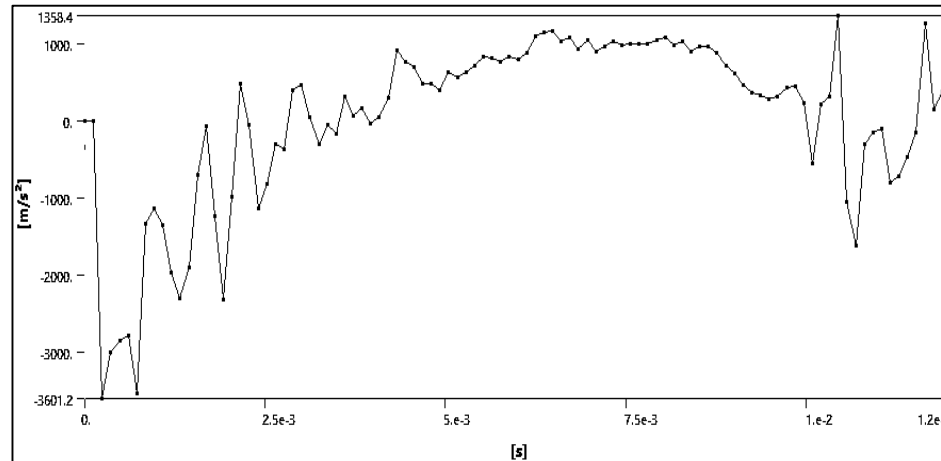
Hollow
beam
(Case 1)



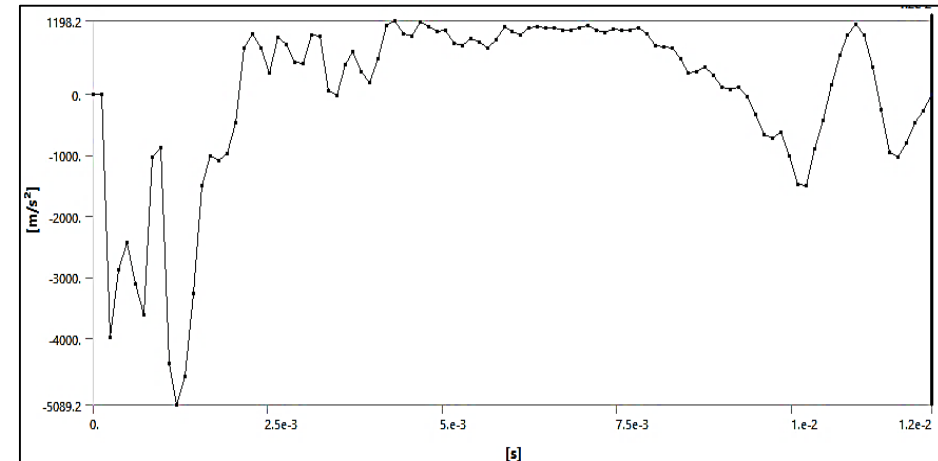
Hollow
beam
(Case 3)



PU-filled
beam with
density
40kg/m³
(Case 2)

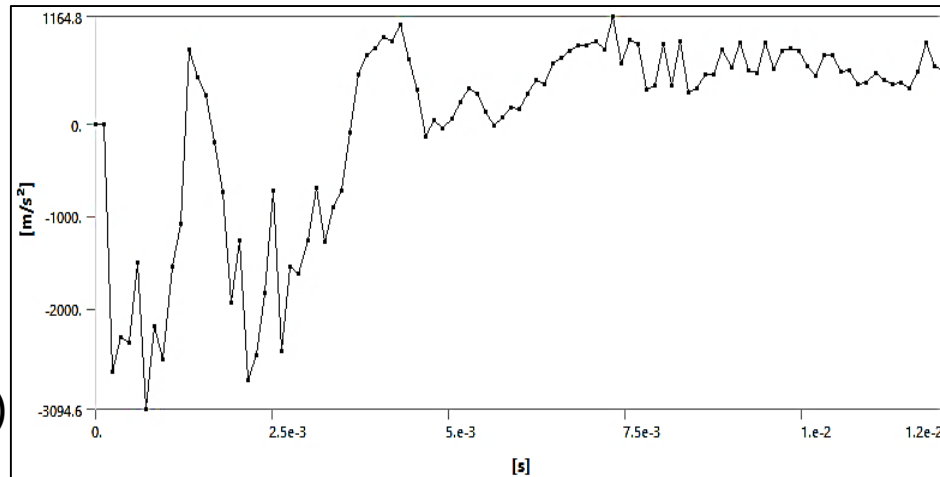


PU-filled
beam with
density
93kg/ m³
(Case 4)

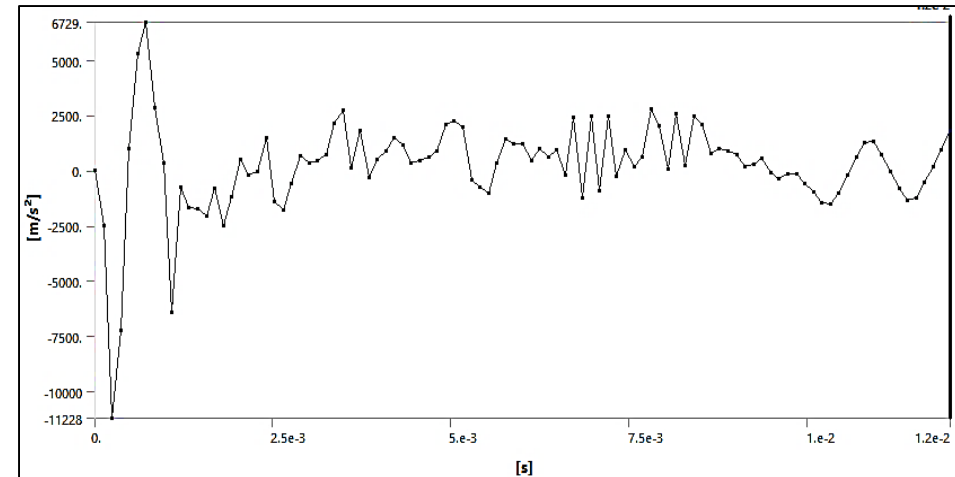
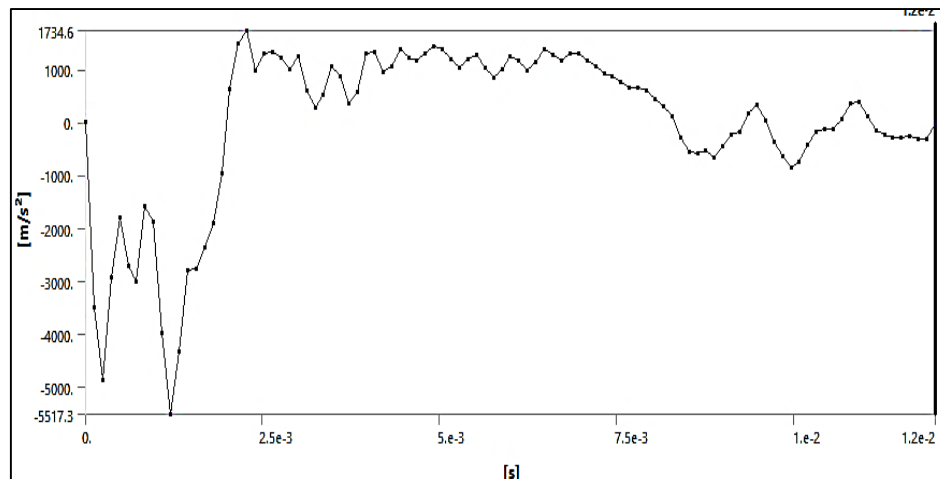


Results – [Acceleration-time]

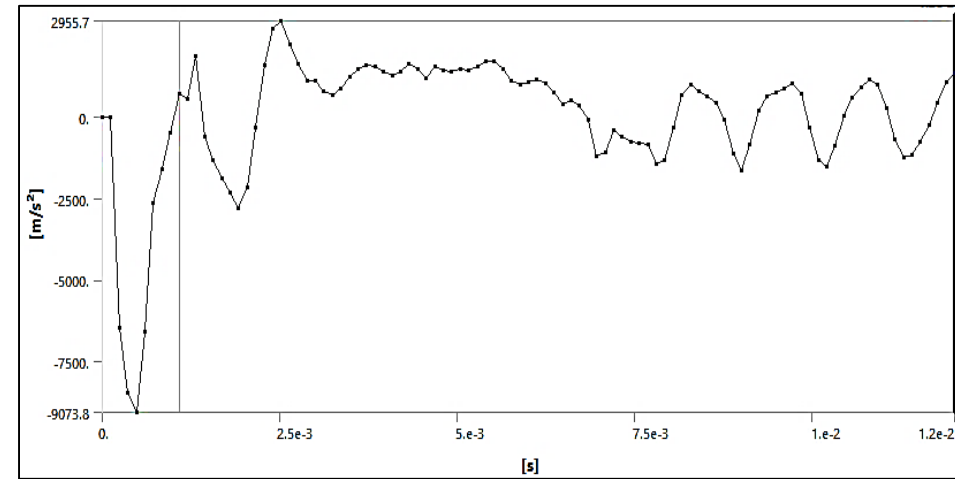
PUF-filled
beam with
density
 93kg/m^3
(Case 5 -
nonbonded)



PUR-filled
beam with
density
 93kg/m^3
(Case 6)



Two-channel
Hollow beam
(Case 7)



Two-channel
PU-filled
beam with
density
 93kg/m^3
(Case 8)

Results – Summary



Polyurethane foam 40 kg/m³

Type	Hollow (w/o foam)	Foam Bonded	Foam non-Bonded
Weight	4.74 kg	4.73	4.75
Thickness of skin	2.13 mm	2.0 mm	
End Time	12 ms (0.012 sec)		
Max. Deformation (mm)	96mm	77	107
Equivalent Plastic Strain (m/m)	0.237	0.198	0.25
Reaction Force (N)	13450	13428	12750

Polyurethane foam 93 kg/m³

Type	Hollow (w/o foam)	Foam Bonded	Foam Non-Bonded	Foam Bonded - Rigid
Weight	5.11	5.12	5.12	5.12
Thickness of skin	2.3mm	2.0mm	2.0mm	2.0 mm
End Time	12 ms (0.012 sec)			
Max. Deformation (mm)	87mm	66mm	98mm	54mm
Equivalent Plastic Strain (m/m)	0.22	0.18	0.24	0.16
Reaction Force (N)	15394	14617	12546 (u=0.1)	14384

Results – Summary



Two channel beam		
Polyurethane foam 93 kg/m3		
Type	Hollow (w/o foam)	Foam Bonded
Weight	6.06	6.07
Thickness of skin	2.24 mm	2 mm
End Time	12 milli-second	12 milli-second
Max. Deformation (mm)	68	52
Equivalent Plastic Strain (m/m)	0.234	0.244
Reaction Force (N)	28800	25000

Conclusion



- i. PU foam filled beams are stiffer as compared to hollow beams of similar weight.
- ii. Reaction forces experienced in the PU foam beams are less than the hollow beams.
- iii. PU foam beams experiences low acceleration levels during impact.
- iv. PU foam filled beam have good ability to absorb Kinetic energy due to its viscoelastic nature.
- v. Non-bonded foams give better results in terms of reduction of reaction forces while less stiff as compared to bonded foams.

