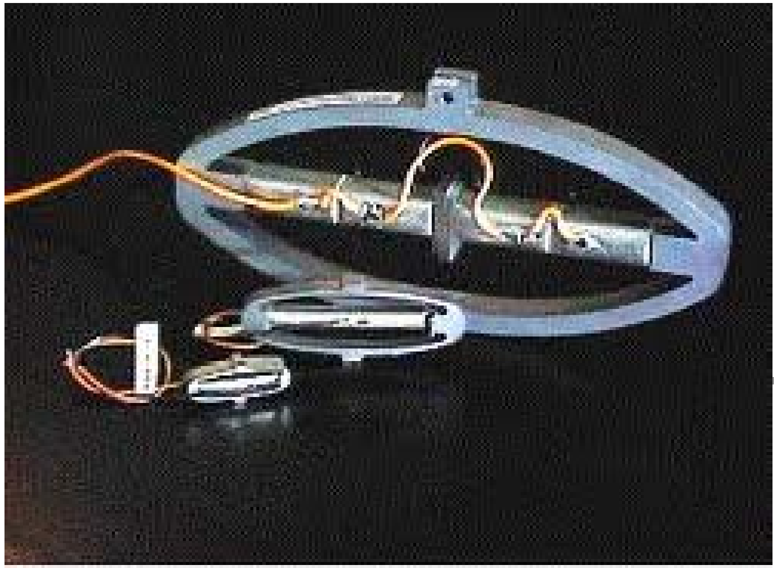
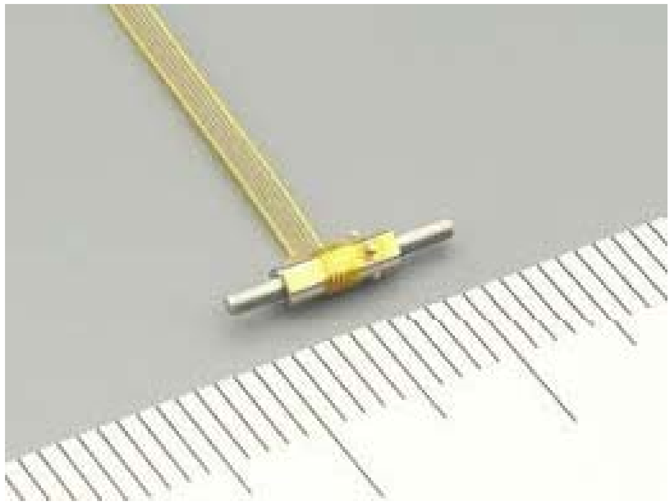


APA230L, APA150M, APA100S

Module 5: Sensors based on HBLS Smart Materials



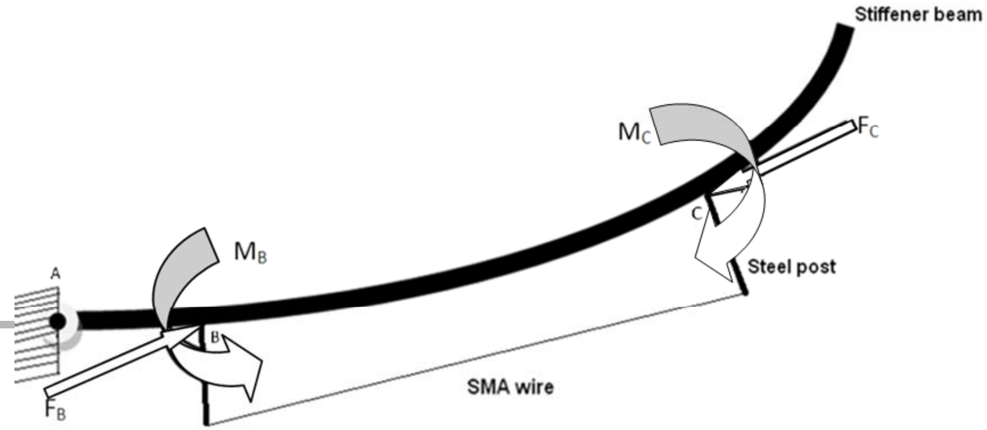
Bishakh Bhattacharya and Nachiketa Tiwari

Department of Mechanical Engineering

Indian Institute of Technology, Kanpur

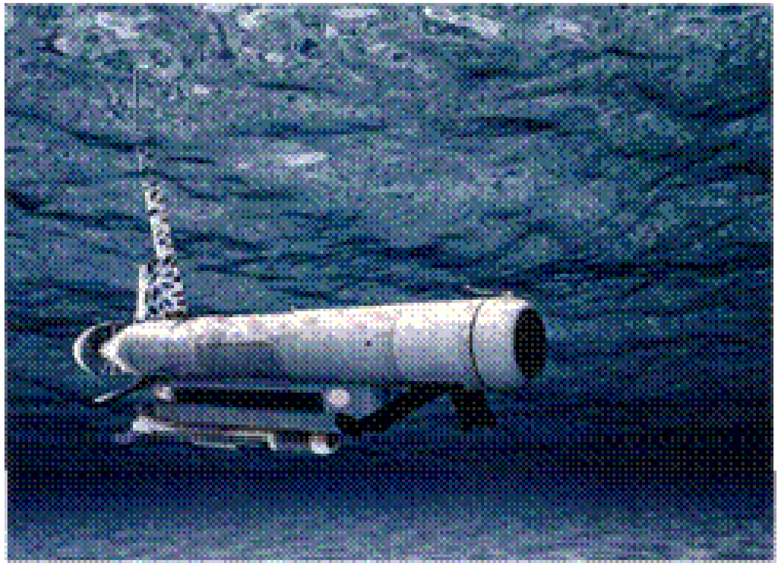
Topics Covered in the Last Lecture

- ❖Introduction to HBLS Materials
- ❖Smart Magnetostrictive Material
- ❖Modelling of Smart Laminated Beam
- ❖Basic Assumptions
- ❖ Distributed Control of the System



LECTURE 35
Delamination Sensing and Vibration Control using Magnetostrictive Materials (Part 1)

Magnetostrictive Material: High Bandwidth-Moderate Strain Actuation



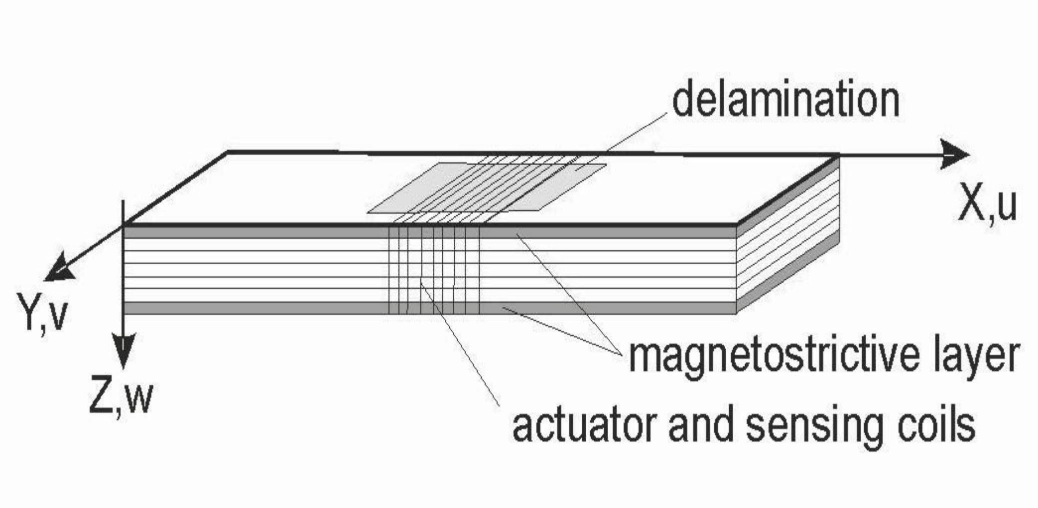
- **DC to 3 KHz Bandwidth**
- **Force availability reported up to 1700 N**
- **Free Strain: 3000 micron**

TALON (Tactical Acoustic Littoral Ocean Network) sonar system uses Magnetostrictive Terfenol-D for under-water submarine detection, source: Etrema Products

Organization of this Lecture

- Delamination in Laminated Composite
- Sensing Delamination
- Terfenol-D as a transducer

Composite laminates with magnetostrictive Smart Layer



Delamination

Separation of plies from one another

Delamination may occur during:

- assembly & handling
- under service
- fabrication
- under impact loading

Effect of delamination

- affects compressive strength
- non-transference of shear across the plies
- leads to fibre breaking, matrix cracking
- may cause bending stretching coupling
- degradation of fibre and fibre matrix interface
- may cause moisture absorption

Damage detection in composite structures: Challenges

- Anisotropy in composite structure.
- Conductivity of the fibres
- Insulative properties of matrix
- Much of the damage occurs beneath the top surface (BVID)

Traditional methods of testing cracks/delamination

- Ultrasonic testing
- Acoustic emission
- Eddy current
- X-radiography
- Thermography
- Lamb wave method

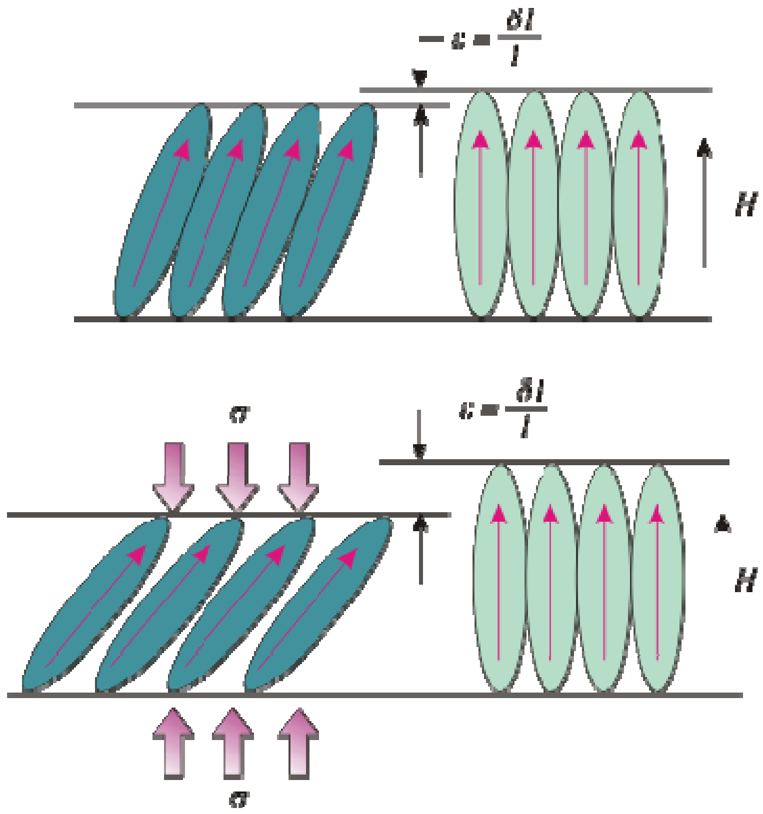
Limitations of NDE

- real time evaluation is difficult
- require specialized equipments
- require skilled manpower
- involves down time, cost, inconvenience
- in-situ evaluation not always feasible

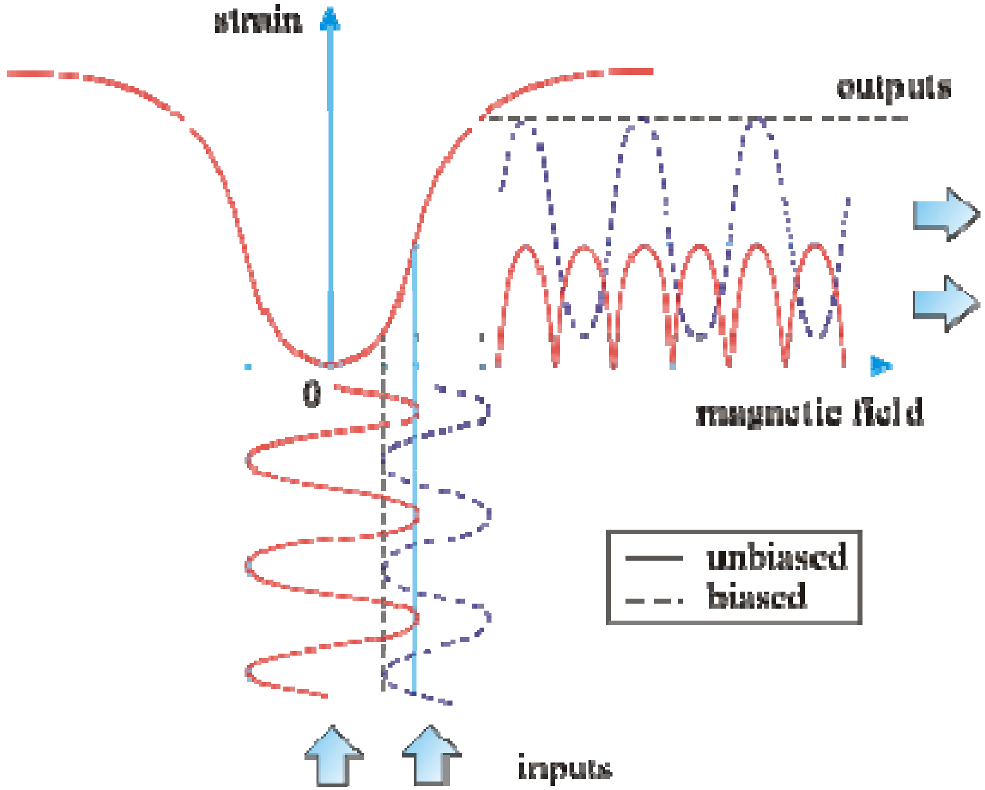
The physics of magnetostriction

- Magnetic field causes crystals within material to rotate
- Internal magnets get realigned. The rotation causes the strain and thus material elongation

Basis of magnetostriction and effect of prestressing



Effect of magnetic bias on the strain produced by a magnetostrictive transducer



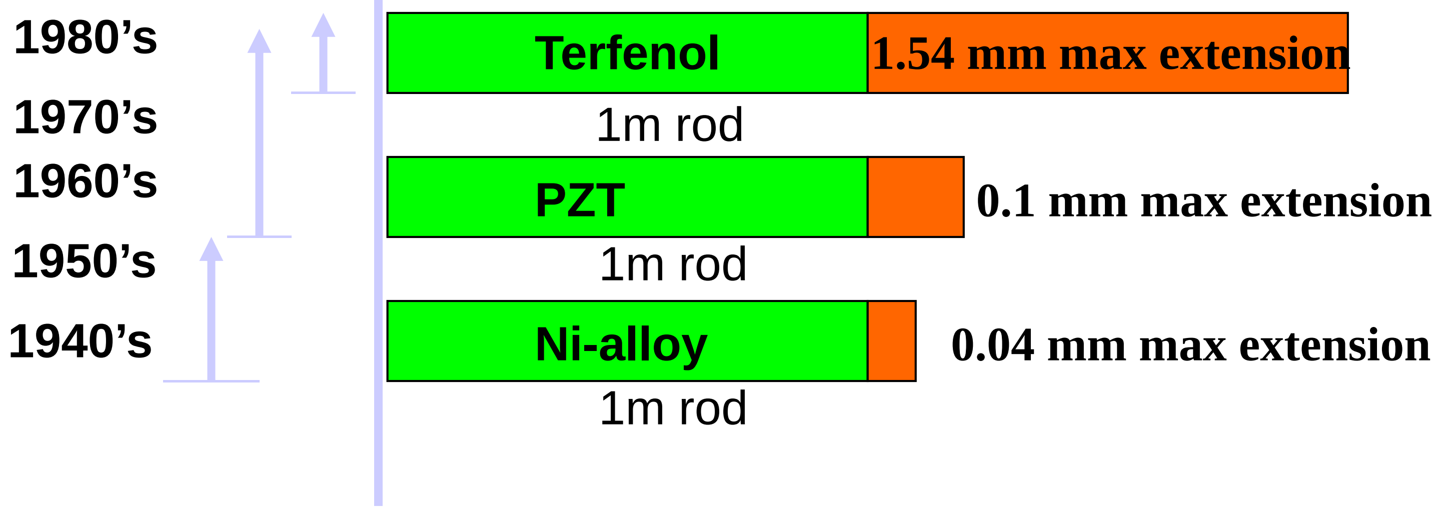
Magnetostriction

- Joule Effect:

  A magnetostrictive material strains in the presence of magnetic field. (*used in actuators*)
- Villari Effect:

  In the presence of external mechanical force, the magnetic state of material changes (*used in sensors*)

Development of magnetostrictive materials



Magneto-mechanical coupling

The one dimensional constitutive relationship for magnetostrictive Material

$$\varepsilon = S^H \sigma + d H$$

$$B = d \sigma + \mu^\sigma H$$

S^H - elastic compliance at constant magnetic field intensity H

μ^σ - permeability measured at constant stress

d - piezomagnetic coefficient

B - flux density

References

[1] Anjanappa, M. and Bi, J., "A theoretical and experimental study of magnetostrictive mini actuators," Smart Materials and Structures, **3**, 83-91 (1994)

[2] Anjanappa, M. and Bi, J., "Magnetostrictive mini actuators for smart structural applications," Smart Materials and Structures, **3**, 383-90 (1994)

[3] Krishnamurthy, A.V.,Anjanappa, M. and Wu, Y-F., "Use of magnetostrictive particle actuators for vibration attenuation of flexible beams," Journal of Sound and Vibrations, **206**, 33-49 (1997)

[4] Krishnamurthy, A.V., Anjanappa, M., Wu, Y.F., Bhattacharya, B. and Bhat, M.S, "Vibration suppression of laminated composite beam using embedded magnetostrictive layers," IE (I) Journal of Aerospace, **78**, 38-44 (1998)

[5] Reddy, J.N. and Barbosa, J.A., "Vibration suppression of laminated composite beams," Smart Materials and Structures, **9**, 49-58 (2000)

[6] Kumar, M. and Krishnamurthy, A.V., "Sensing of delamination in smart composite laminates," Journal of Aeronautical Society of India, **51**, 79 (1998)

Acknowledgement: Dr. Anand Kumar, HBTI for Research and Developing the Slides