High speed Experimental Mechanics Laboratory

Laboratory Coordinator: Dr. P. Venkitanarayanan

Associated Faculty Members (if any):

List of Major Equipment:

- SIM02-16 Utra high speed camera
- Photran SA1.1 high speed cameras for stereo imaging
- 25 KN UTM
- Digital Image correlation System (2D and 3D)
- Split Hopkinson pressure bars (tension & compression)
- High speed data acquisition systems (10 MHz sampling)
- 200 KHz bandwidth 6 channel strain conditioner
- 3 MHz bandwidth 2 channel strain conditioner
- Convective Oven
- Probe Sonicator
- 4 Channel Digital Oscilloscope
- Leica stereo microscope

Brief description of the laboratory:

Please provide a brief description of the laboratory in about 8-10 lines, focusing on the main thrust area of the laboratory activities.

The activities in this laboratory focus on understanding the response and failure of materials when subject to extreme conditions as in high-speed impact and high strain rate loading. The facilities such as split Hopkinson pressure bars capable of testing soft gels to armor grade ceramics have been designed and built indigenously. Coupled with ultra-high speed imaging and high speed image correlation, we are able to capture in real-time the response and also evolution and propagation of damage in a variety of materials such as armor grade ceramics, fiber composites, fiber metal laminates, polymers, concrete and rocks.

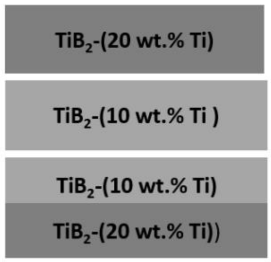
Laboratory research keywords:

High strain rate mechanics, impact mechanics, dynamic fracture, ceramics, fiber metal laminates, fiber composites, rocks

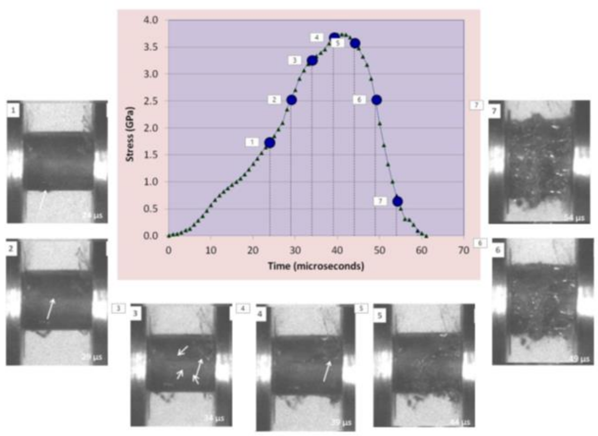
Major Research and Development Contribution of the Laboratory

Year	Major research and development activity
2020-2021	▪ Study of delamination and deboning in adhesive joints and layered systems through the shaft loaded blister test (SLBT) under dynamic loading. Test are performed from which the far field responses like deformation and force histories are recorded synchronously with high-speed images which provide the propagation of de-bond. Using this information parameters of the cohesive zone models (CZ) are determined.
2019-2020	▪ Study of de-bonding in layered materials using SLBT and evaluating the de-bond energy (toughness) profile. The effect of deboning layer thickness and level of out of plane deformation affects the mode-mixity during debonding. This was characterized through numerical analysis and a new scheme of data reduction was developed to determine the toughness as a function of the mode-mixity. The same was used in FE simulations with CZ to simulate the experimentally observed de-bonding process.
2018-2019	▪ In collaboration with Department of Earth Science, the formation of fragments when rocks which are isotropic and rocks which had a foliated structure, were subjected to high strain rate tensile loading. The study brought out valuable insights into the formation of fractures in rocks. ▪ The kinetics involved in texture development in Al-Mg alloy was investigated when the alloy was subjected to high strain rate tensile loading. High speed DIC was used to obtain the full field strain history in the specimen so that subsequent texture analysis can be correlated to the accumulated strain in the specimen. This work was in collaboration with Department of Material Science and Engineering. HSEML was primarily involved in the high strain rate experiments ▪ High entropy alloys (HEA) are a recent innovation. Deformation behaviour of FCC CoCuFeMnNi single phase high entropy alloy (HEA) was studied at strain rate of 0.001/s and 3000/s in collaboration with the Department of Material Science and Engineering. The material showed high strain rate hardening as well as higher strain hardening due to the operation of deformation twinning which was observed from EBSD of tested samples.
2017-2018	▪ The response and failure of fiber metal laminates (FML) subjected to high strain rate tension was investigated. FMLs having different layer sequences but the same metallic volume fraction were prepared and subjected to high strain rate tension. The evolution of strain and damage was imaged using two high speed cameras. The strength of the FMLs were not significantly different however, relative placement of the metallic layers had an effect on the damage progression. ▪ The effect of glass fillers on the high strain rate response of epoxy was studied in collaboration with Department of Aerospace Engineering. The effect of the shape and volume fraction of the glass fillers on the compressive strength was established through this study
2016-2017	▪ The effect of circular perforations on the progressive collapse of circular tubes when subjected to axial impact was studied through experiments and

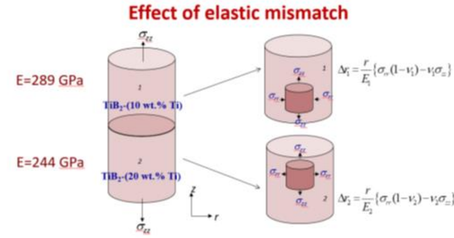
	numerical simulation. Hole configurations which can provide peak load reduction without compromising the energy efficiency were identified ▪ The effect of metal layer positioning on the tensile response and damage progression of FMLs when subjected to quasi-static tensile loading was studied. The relative position of the metallic and composite layers had a significant influence on the post peak response. Numerical simulations were also performed to gain more insight into the mechanics involved. ▪ The effect of metal layer positioning on the energy absorption and damage progression of FMLs when subjected low velocity impact loading was studied. The relative position of the metallic and composite layers had a significant influence on the damage progression. Numerical simulations were also performed to gain more insight into the mechanics involved.
2015-2016	▪ The effect of multiple perforations on the collapse characteristics of stubby cylinders was investigated through SHPB experiments and FE simulations. ▪ Fracture propagation in layered plates having elastic mismatch when subjected to in-plane dynamic bending was studied. ▪ An analytical investigation was carried out to understand the effect of elastic gradient along the crack front on the crack-tip fields for a propagating crack in a graded material



Material	Compressive Strength (GPa)	Hardness (GPa)	Fracture toughness (MPa-m$^{1/2}$)
TiB_2-10%Ti	**4.6 ± 0.6**	**41.7 ± 2.9**	**11.8 ± 1.4**
TiB_2-20%TI	**4.0 ± 0.4**	**38.0 ± 2.3**	**12.1 ± 1.1**
Bi-layer	**3.7 ± 0.4**		



Effect of elastic mismatch



$$\sigma_{rr} = \sigma_{\theta\theta} = \frac{E_2\nu_1 - E_1\nu_2}{E_2(1-\nu_1) + E_1(1-\nu_2)}\sigma_{zz} = \alpha\sigma_{zz}$$

- When σ_{zz} is compressive, σ_{rr} and $\sigma_{\theta\theta}$ will be tensile in the stiffer layer (layer 1)

- Tensile stresses in the stiffer layer because of the elastic mismatch can adversely affect the compressive strength of the bi-layer composite

Figure #1: Weaking of bi-layer ceramics due to elastic mis-match

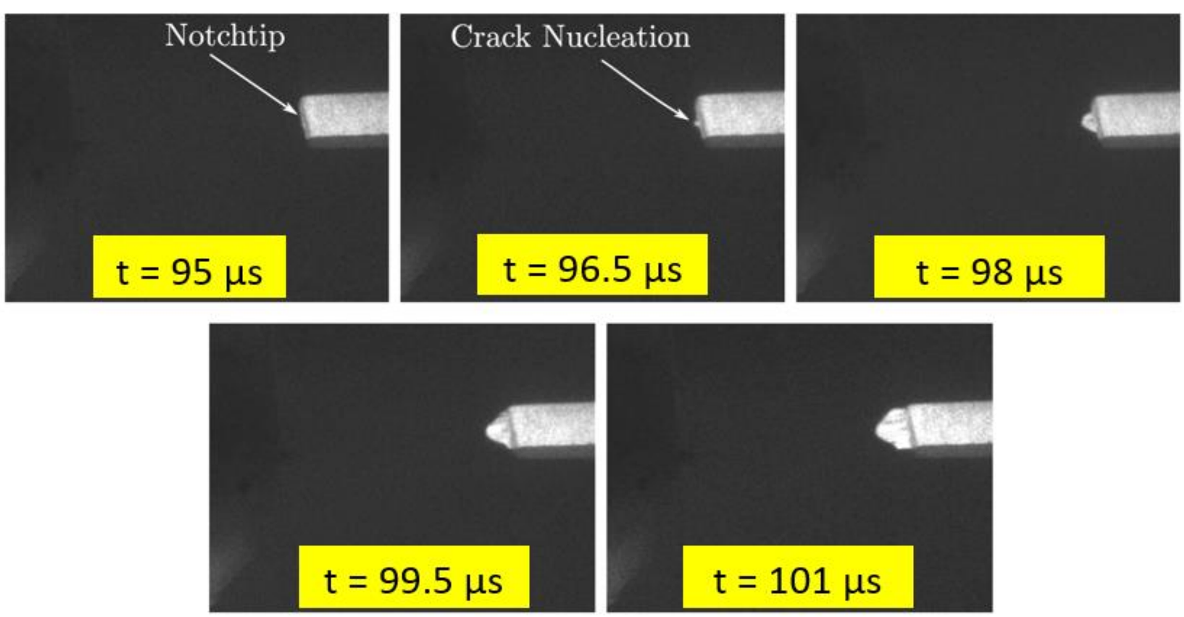


Figure #2: Crack nucleation and growth in PMMA under impact loading

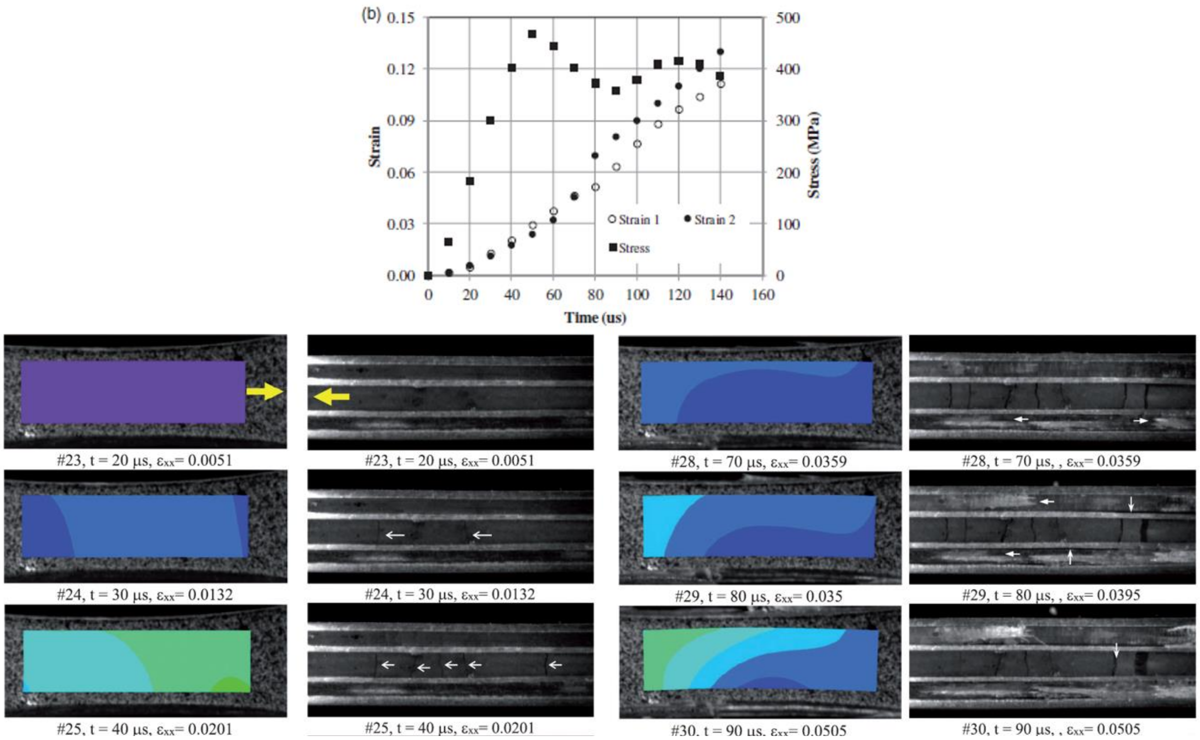


Figure #3: Strain and dagame correlation in FML under high strain rate tensile loading