IRFAN SHIRAZI

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PROFESSIONAL SUMMARY

Researcher and MSCA Seal of Excellence holder specialising in AI-driven structural health monitoring of composite structures, with direct application to wind energy and aviation. My work bridges machine learning and physical engineering systems to deliver reliable, interpretable diagnostics, moving beyond black-box models toward solutions that industry can actually trust and deploy. I am ready to translate this expertise into measurable sustainability impact through close collaboration with Irish industry.

EDUCATION

Ph.D. in Electromechanical Engineering | Ghent University, Belgium
Thesis: Vibration-Based Structural Health Monitoring of Composites Using Neural Networks

M.Sc. Mechanical Engineering (Research) | Universiti Teknologi PETRONAS, Malaysia *Thesis: Fiber orientation in metal injection molded short carbon fiber reinforced copper matrix composite*

B.Sc. Metallurgy & Materials Engineering | University of The Punjab, Pakistan

TECHNICAL SKILLS

Machine Learning & Artificial Intelligence

- **Machine Learning:** 1D-CNNs, ANNs
- **Optimization Techniques:** Metaheuristic Algorithms, Hyperparameter Tuning, Genetic Optimization Algorithm, Bayesian Optimization Algorithm
- **Emerging Focus:** Causal machine learning, interpretability, and explainable AI (XAI)

Programming & High-Performance Computing

- **Languages:** Python, MATLAB
- **HPC & Deployment:** High-Performance Computing (HPC) cluster management, Parallel Computing

Engineering & Computational Mechanics

- **Simulation:** Finite Element Analysis (FEA) using ABAQUS
- **Structural Dynamics:** Vibration Analysis, Modal Analysis, Time-Series Signal Processing

Interdisciplinary Collaboration: Worked across mechanical engineering, materials engineering and computer science

Materials Characterization & Processing:

- **Characterization Techniques:** Scanning Electron Microscopy (SEM), Thermal Analysis (TGA, DSC), Metallography

- **Materials Processing:** Powder Injection Moulding (PIM), Composite Fabrication, Extrusion, Sintering

RESEARCH EXPERIENCE

Doctoral Researcher | Ghent University, Belgium | 2019-2024

Conducted doctoral research focused on developing machine learning frameworks for damage detection in engineering structures.

- **Data-Driven Models for Damage Detection:** Developed AI-powered frameworks (1D-CNNs, ANNs) to solve inverse problems—inferring damage presence, location, and severity from sensor data. Achieved high-accuracy damage characterization even under limited data conditions, demonstrating the power of machine learning for predictive maintenance and structural assessment.
- **Computational & Experimental Integration:** Engineered end-to-end workflows combining finite element simulations (Abaqus) with experimental validation, signal processing, and feature extraction. This multi-scale modelling approach mirrors industry needs for virtual testing and digital twin development in aviation.
- **Optimization & Efficiency:** Accelerated neural network training by upgrading standard backpropagation with metaheuristic optimization techniques (e.g., Particle Swarm Optimization), improving model convergence and efficiency.
- **Interdisciplinary Collaboration:** Collaborated with international, multidisciplinary research teams spanning mechanical engineering, materials science, and computer science. Contributed to experimental design, knowledge exchange, and co-authored publications, demonstrating ability to work across boundaries; essential for linking education, research, and industry.
- **Research Output & Communication:** Published research outcomes in high-impact journals (e.g., *Composite Structures*) and presented at international conferences, demonstrating ability to communicate complex findings effectively—skills valuable for supervising student projects and contributing to the research community.
- **Proposal Writing & Project Coordination:** Contributed to drafting research proposals for funding schemes including FWO and MSCA.

Graduate Researcher | Universiti Teknologi Petronas, Malaysia | 2011-2014

Conducted materials science research on advanced composites for thermal management applications.

- **Materials Development Lifecycle:** Managed the complete development of lightweight, high-thermal-conductivity composites for heat sink applications, including feedstock preparation (twin-screw extrusion), debinding, sintering, and thermo-physical property characterization. This end-to-end experience provides practical insight into materials processing relevant to aviation manufacturing and repair.
- **Microstructure Characterization:** Characterized fiber orientation and dispersion using Scanning Electron Microscopy (SEM), establishing critical links between processing parameters and microstructural outcomes. This expertise in failure mechanisms and materials characterization directly supports teaching and research on aircraft structures and maintenance.
- **Thermal & Rheological Analysis:** Conducted thermal analysis (TGA, DSC) and rheological characterization to link material behavior to processing parameters.

- **Industry-Relevant Skills:** Developed hands-on expertise in powder injection moulding (PIM), extrusion, and sintering.

PUBLICATIONS & DISCOURSE

Journal Publications

1. **MI Shirazi**, S Khatir, D Boutchicha, MA Wahab, Feature extraction and classification of multiple cracks from raw vibrational responses of composite beams using 1D-CNN network, Composite Structures 327: 117701, 2024. https://doi.org/10.1016/j.compstruct.2023.117701
2. **MI Shirazi**, S Khatir, B Benaissa, S Mirjalili, MA Wahab, Damage assessment in laminated composite plates using modal Strain Energy and YUKI-ANN algorithm, Composite Structures, 303: 116272, 56, 2023. https://doi.org/10.1016/j.compstruct.2022.116272
3. S Ali, F Ahmad, **MI Shirazi**, K Malik, MR Raza, IR Memon, Flow induced fiber orientation in short carbon fiber reinforced copper matrix composites, Materials Today Communications 33: 104855, 2022. https://doi.org/10.1016/j.mtcomm.2022.104855
4. F Ahmad, M Aslam, MR Raza, AS Muhsan, **MI Shirazi**, Experimental Investigation on Thermal Conduction of Carbon Nanotubes Reinforced Copper Matrix Composites, Applied Mechanics and Materials 564, 455:460, 2014. https://doi.org/10.4028/www.scientific.net/AMM.564.455

Conference Proceedings & Posters

5. **MI Shirazi**, S Khatir, M Abdel Wahab, Quantification of two separate cracks by retrieval of relevant features from vibrational data using a deep 1D CNN network, The 6th International Conference on Numerical Modelling in Engineering (NME2023).
6. **MI Shirazi**, S Khatir, M Abdel Wahab, Extracting damage features from vibrational response in a cracked simple beam using convolutional neural networks, The 11th International Conference on Fracture Fatigue and Wear (FFW 2023).
7. **MI Shirazi**, MA Wahab, Optimizing the hyperparameters of 1D-CNN networks using Genetic algorithms, 2nd International Conference on Applied Mathematics, Informatics, and Computing Sciences (AMICS2023).
8. F Ahmad, M Aslam, K Altaf, **I Shirazi**, Effects of mold geometry on fiber orientation of powder injection molded metal matrix composites, AIP Conference Proceedings 1669 (1)2015,
9. **I Shirazi**, F Ahmad, MR Raza, A Muhsan, M Aslam, Shear controlled alignment of short carbon fibers in copper matrix composite green samples produced by powder injection molding, AIP Conference Proceedings 1669 (1) 2015
10. **MI Shirazi**, F Ahmad, MR Raza, AS Muhsan, MA Omer, M Aslam, Orientation of carbon fibers in copper matrix produced by powder injection molding, MATEC Web of Conferences, 13, 04027, 2014
11. M Aslam, F Ahmad, PSMBM Yusoff, N Muhamad, MR Raza, **MI Shirazi**, Effects of admixed titanium on densification of 316L stainless steel powder during sintering, MATEC Web of Conferences 13, 04026, 2014.

INDUSTRIAL EXPERIENCE

Junior Engineer | Munir Steel Castings, Lahore, Pakistan | 2009 – 2011

CURRICULUM VITAE

Gained a practical, ground-level perspective on the manufacturing and quality challenges of producing performance-critical alloy components. This role provided foundational experience in solving real-world materials engineering problems within a dynamic production foundry environment.

- Practical Manufacturing: Managed key stages of the casting process
- Quality Analysis & Problem-Solving

Internee | Pakistan Ordnance Factories | 2007

- Report on the different manufacturing processes undertaken, from sheet metal forming to rolling and surface treatment, at the diverse factories

ACADEMIC EXPERIENCE

Lecturer |

COMSATS University Islamabad, Pakistan | 2015 – 2019

Full-time faculty position with responsibilities in curriculum development, student mentorship, and academic administration.

- **Taught undergraduate courses** in Manufacturing Processes I & II, Engineering Physics, and Engineering Materials to cohorts of 50+ students per semester, consistently receiving positive student evaluations.
- **Served as core member** of the Outcome-Based Education (OBE) Implementation Committee, leading curriculum alignment with national accreditation standards and organizing faculty workshops to prepare for the inaugural 2019 audit.
- **Supervised two undergraduate final-year projects**, guiding students through research methodology, experimental design, and technical writing.
- Advised a cohort of 50+ students as Batch Advisor, providing holistic support on academic progression, career planning, and financial challenges to ensure student success and retention.

Graduate Assistant | University of Technology, Petronas, Malaysia | 2011 – 2014

Provided instructional support for undergraduate courses while pursuing M.Sc. by research.

- **Delivered tutorial sessions** in Engineering Materials for students across Chemical, Civil, Mechanical, and Petroleum Engineering programs, serving 25+ students per semester to reinforce core lecture concepts.
- **Conducted laboratory demonstrations** for Engineering Physics courses, guiding students through experimental procedures and data interpretation.

AWARDS, HONORS & KEY ACHIEVEMENTS

- Achieved the **Seal of Excellence** (90% score) on **Marie Skłodowska-Curie Actions (MSCA) Postdoctoral Fellowship** application (2025 call), for a project on responsible AI implementation; proving capacity to develop competitive, high-quality research proposals.
- Secured a COVID-19 **special research fund**, receiving external validation of research adaptability and potential during a period of unprecedented disruption.
- **Awarded a Graduate Assistantship** for M.Sc. by Research at Universiti Teknologi PETRONAS, Malaysia in recognition of research potential.
- Awarded a merit-based scholarship for ranking in the **top 1%** of the department during my second year of undergraduate studies; recognizing outstanding academic performance.

- Ranked in the **top 5%** of my Bachelor's cohort at the University of the Punjab, demonstrating consistent academic excellence throughout undergraduate studies.

PROPOSALSUMMARY

Feature-relevant Artificially Intelligent Responsible Structural Health assessment in Aerospace and Renewable Energy Infrastructures (FAIR SHARE)

Introduction: Structural Health Monitoring (SHM) is essential for ensuring the safety and reliability of composite-intensive aerospace and renewable energy structures, where early and accurate damage detection is critical. While Artificial Intelligence (AI) and Machine Learning (ML) have shown significant potential, current approaches often lack reliability due to their difficulty in distinguishing true damage signatures from spurious label associations. This limitation reduces trust in predictions and necessitates large damaged-condition datasets, restricting applicability in real-world structures. This project directly addresses these challenges by decoupling and characterizing Ultrasonic Guided Wave (UGW) interactions arising from material properties, geometry, and damage. Beyond improving interpretability and confidence in predictions, this decoupling and characterization enables transferable learning: damage features can be captured from a small sacrificial specimen and combined with structural features from a larger asset. This removes the need for damage data from full-scale operational structures. The resulting modular framework allows a single damage-trained ML model to be adapted across multiple large structures made of the same material, paving the way for scalable, trustworthy, and resource-efficient SHM solutions.

Problem Statement: Ultimately, ML-based SHM through ultrasonic guided waves faces two challenges:
(i) extracting reliable damage features from inherently complex UGW data, and
(ii) overcoming the operational uncertainties associated with large-scale structures.

Recent advances in Self-Supervised Learning (SSL) offer a promising alternative for SHM. By generating supervisory signals from the data, these models avoid manual labeling, enabling models to learn rich latent-space representations. These are first trained through pretext tasks and later adapted to the target task via fine-tuning. This capability makes these techniques robust to domain shifts, less sensitive to pretraining variations, and more resilient to class imbalance.

Research Aims: This project aims to disentangle damage features from structural effects in UGW signals, enabling detailed analysis of each damage aspect: its type, size, and location. This seperation allows modular ML algorithms, allowing learned damage features to transfer across structures with similar materials and damage characteristics.

Research Objectives (ROs): Guided by the above challenges and proposed approach, the project is structured around the following research objectives:

- **RO1: Establish experimental and simulation groundwork** to generate data for subsequent objectives.
- **RO2: Decouple damage features in UGW signals** by using SSL models.
- **RO3: Characterize damage features through interpretability and explainability** in models fine-tuned for three unique damage characters (type, size and location of damage) confirming correlation with learned features.
- **RO4: Test the generalization capability of learned damage-specific features** on the same structure with a new sensor arrangement, validating framework transferability at the same scale.
- **RO5: Extend the framework to larger-scale prototype structure**

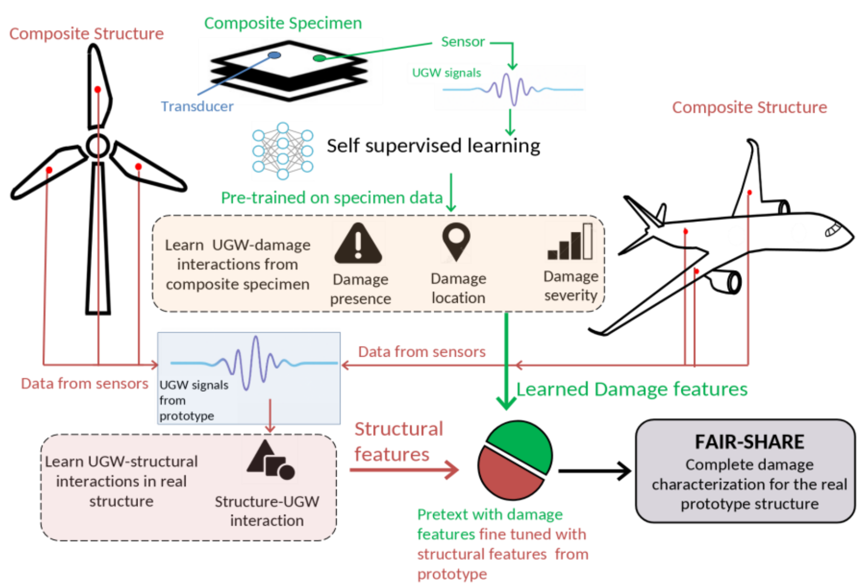

Figure 1 Overview of the project

The project introduces several ***key innovations in SHM with UGWs***:

1. **Feature decoupling:** A novel ML approach that dientangles material- and structure-driven UGW interactions.
2. **Damage characterization through UGWs:** ML models coupled with interpretability tools to explain unique effects of damage characteristics on UGWs.

3. **Feature fusion:** Innovative integration of structural and damage features at a common scale to build unified SHM representations.
4. **Scalable transfer:** Systematic transfer of damage features from sacrificial specimens to large-scale prototype enables modularity, allowing features to be applied across different structures with same material.

The project is ambitious in seeking a fundamental change in how composite structures are monitored: replacing opaque, data-hungry methods with interpretable, transferable, and resource-efficient AI frameworks.

Research Questions: Building on the outlined ROs, this project seeks to address the following questions:
1. *Can UGW interactions between structural features and damage characteristics be effectively decoupled?*
2. *Can the disentangled features be reliably characterized?*
3. *Can these decoupled features be effectively coupled with another structure's features?*

To address the research questions, this project advances the following hypotheses:
1. **Decoupling and characterizing UGW interactions:** Guided wave signals contain separable latent representations of structural (geometry, lay-up, boundaries) and damage-specific features (size, location, type). SSL algorithms on small, intentionally damaged specimens can isolate and characterize these damage features using its latent space.
2. **Transferability of decoupled features:** Damage features extracted via SSL can transfer across structures with similar materials. Controlled Transfer Learning (TL) allow adaptation with minimal target-structure data.

Proposed Methodology: The proposed methodology can be summarized in the Table below.

ROs	Work Packages		Tasks	
RO1	WP1	Project Foundation	*T1.1*	*Define project parameters: selection of damage/sensor locations etc*
			T1.2	*Development of Data Management Plan*
	WP2	Manufacturing	*T2.1*	*Manufacture composite specimen*
			T2.2	*Manufacture prototype*
	WP3	UGW Simulation in composites	*T3.1*	*Create FE model simulating UGW propagation in specimen*
			T3.2	*Create FE model simulating UGW propagation in prototype*
RO2	WP4	Self-Supervised Learning	*T4.1*	*Set up sensors (Configuration 1) on the plate specimen and collect data.*
			T4.2	*Train SSL pretext models on unlabelled UGW data for feature seperation.*
			T4.3	*Evaluate feature separation and compare with FSL*
RO3	WP5	Damage character isolation	*T5.1*	*Fine-tune seperate network for damage character: its type.*
			T5.2	*Fine-tune seperate network for damage character: its location.*
			T5.3	*Fine-tune seperate network for damage character: its severity.*
	WP6	Interpretation & Explanation	*T6.1*	*Use interpretability techniques to understand internal representations.*
			T6.2	*Apply XAI techniques to understand reasons for each network's outputs .*
RO4	WP7	Generalizabilty of Learned features	*T7.1*	*Integrate specialized networks into a single multi-task network.*
			T7.2	*Test generalization using sensor configuration 2: unseen damage conditions.*
			T7.3	*Compare SSL models with supervised baselines for detection performance.*
RO5	WP8	From small to large-scale Transfer	*T8.1*	*Collect data from sensor network on the prototype*
			T8.2	*Fine-tune SSL networks on data from large-scale structures.*

Impact of the project: FAIR-SHARE project strengthens safety, sustainability, and public confidence in renewable energy and aviation. Reliable SHM is vital for wind turbines, where maintenance costs reach 20% of expenses. With the IEA calling for an elevenfold increase by 2050, inefficient maintenance threatens scalability of one of the lowest-cost renewables. Aviation faces similar pressures: airlines spent $18.5 billion on structural repairs, with costs projected at $30 billion by 2033. Enhancing confidence in composite aircraft through AI-driven diagnostics supports passenger safety, 5 million aviation jobs, and CO_2 reduction. ***Scientifically***, the project develops a responsible ML framework to predict damage without requiring actual damage data, scaling specimen-level features to structures.