NATURAL FIBER BASED REINFORCED COMPOSITE AND STRUCTURAL HEALTH MONITORING: POSSIBLE OR FEASIBLE

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- STRUCTURAL HEALTH MONITORING
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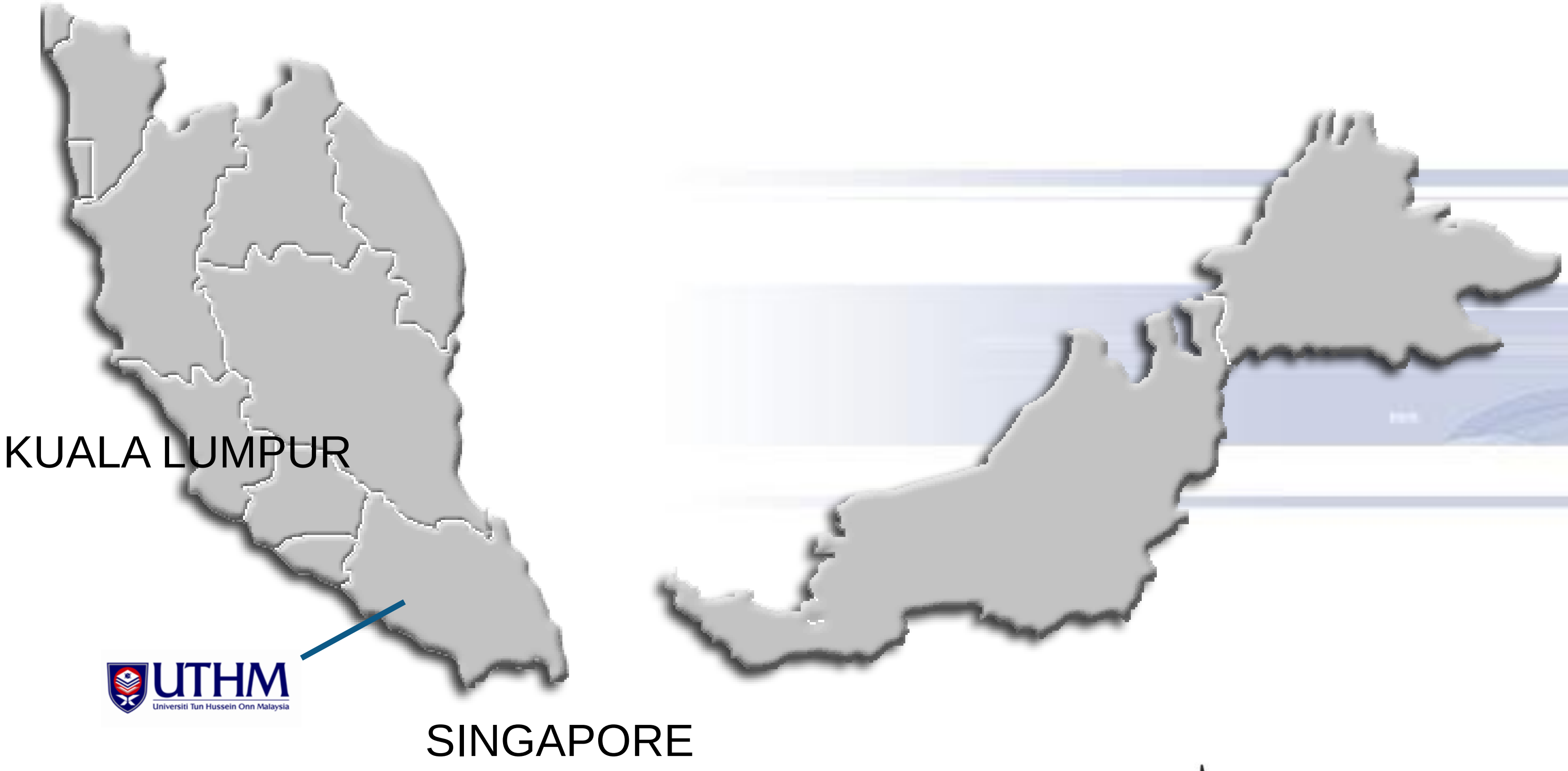
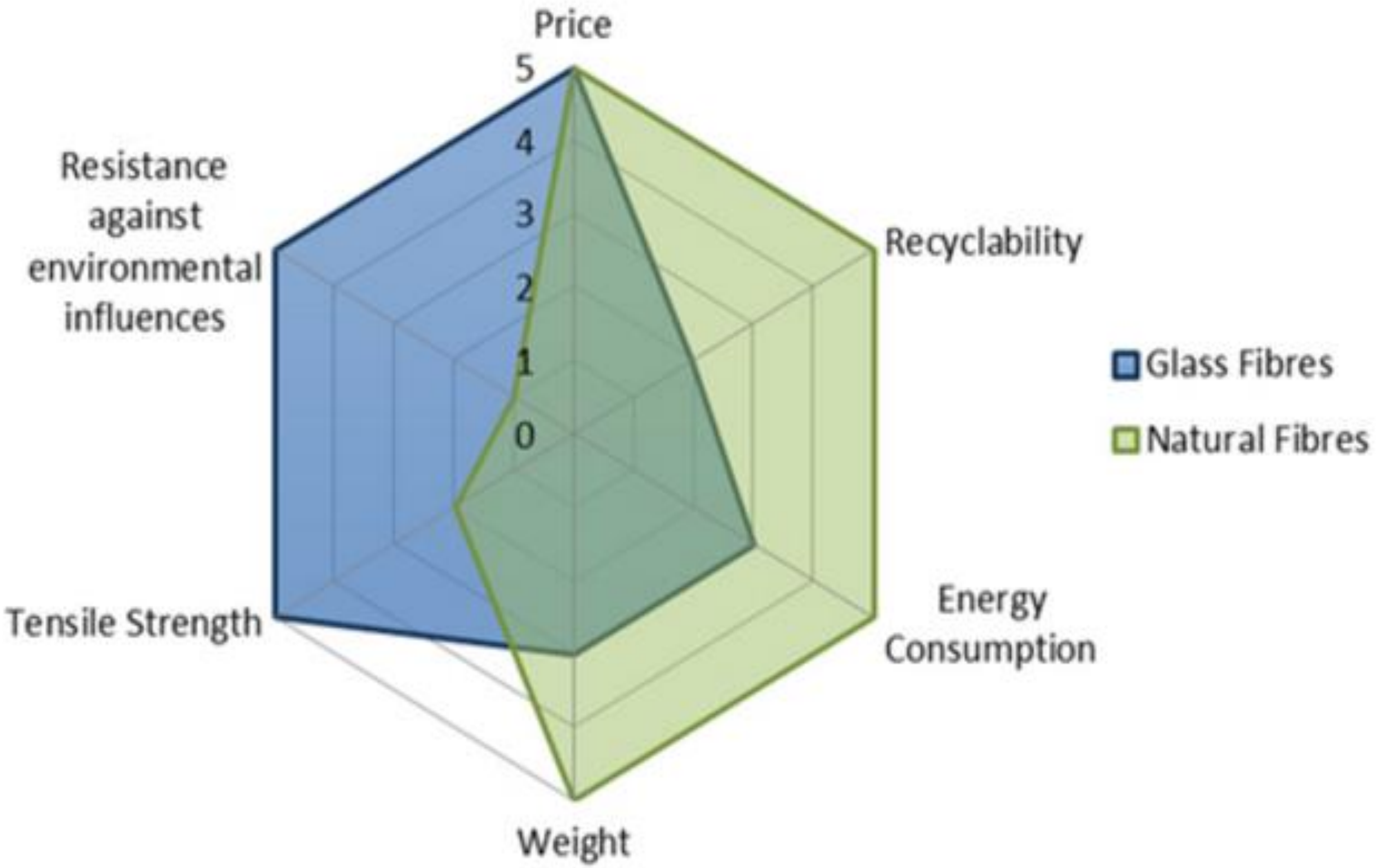
Introduction



Natural Fibre – Why??

1. In developing countries, large amount of agricultural wastes or by-products build up each year.
2. The natural fiber is the largest waste ensuing from the agricultural processing of grains
3. **RECYCLING** of these waste is of rising attention worldwide

Natural vs. Synthetic



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Natural Fiber

- Environmental friendly materials
- Low density
- Lightweight and non-toxicity
- Material cost saving to the plastic industry
- **Higher demand** – replacement current synthetic
- Renewable resources ensures a continuous fibre supply
- **Susceptible to impact damage**

MyFKMP

Applications

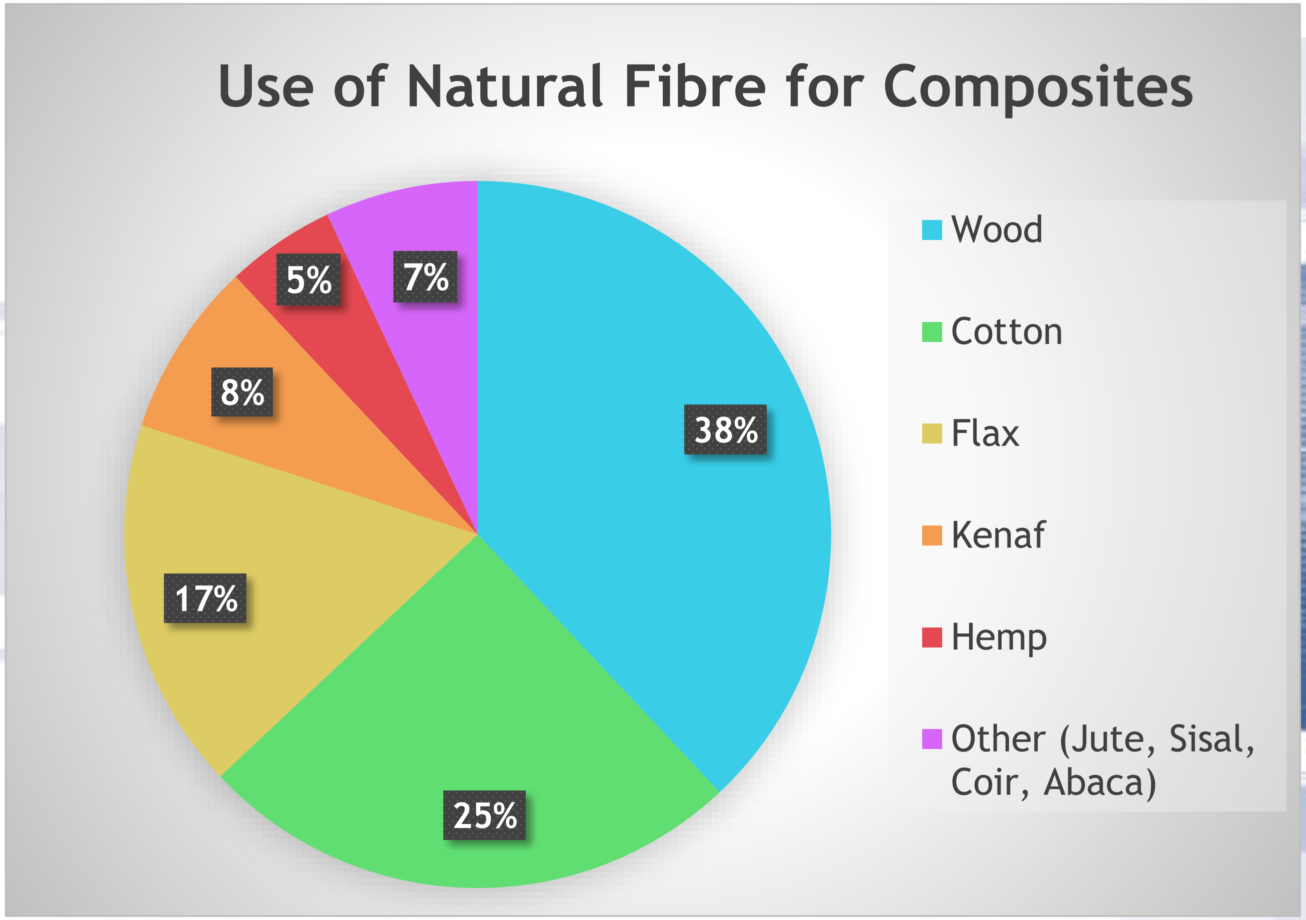
Transportation
- Automobile and railway coach interior
- Boat

Building / Construction industry
- Panel for partition and false ceiling
- Floor, window, door frames

Storage devices
- Post boxes
- Bio gas container

Everyday application
- Lampshades, suitcases, helmets

Furniture
- Chair, table, bath units

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Properties of Several Natural Fibers

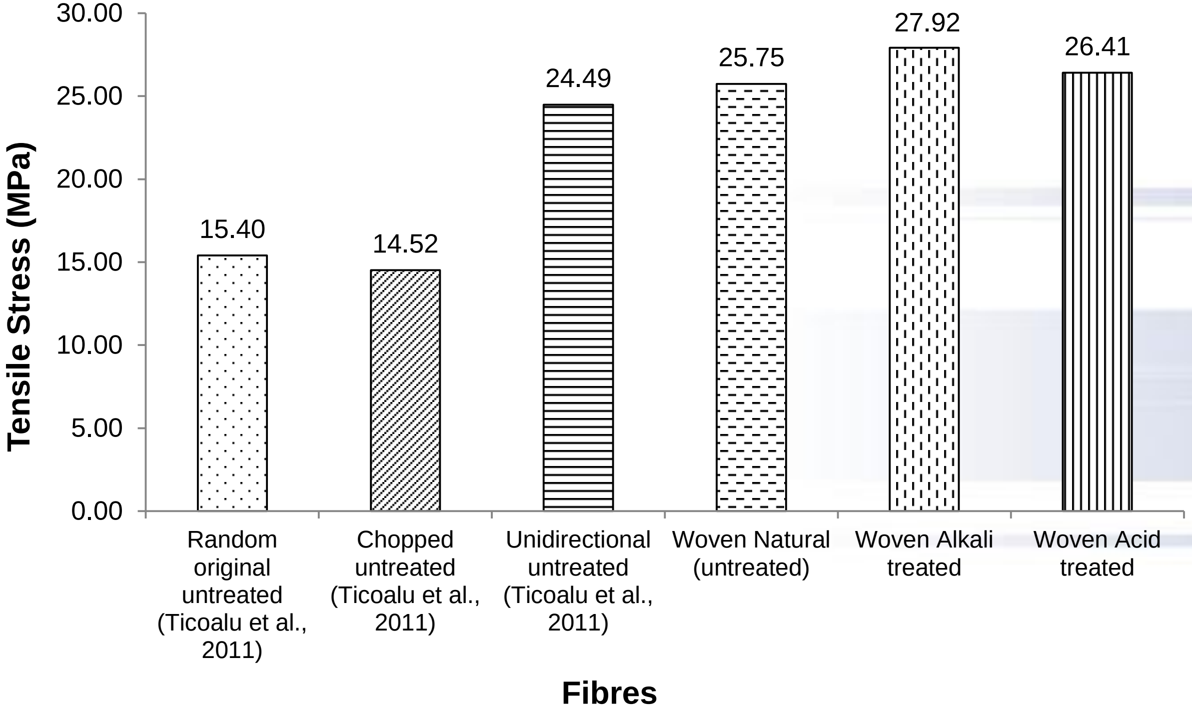
Table 2.1 Properties of natural fibers and synthetic fibers (Ichhaporia 2008)

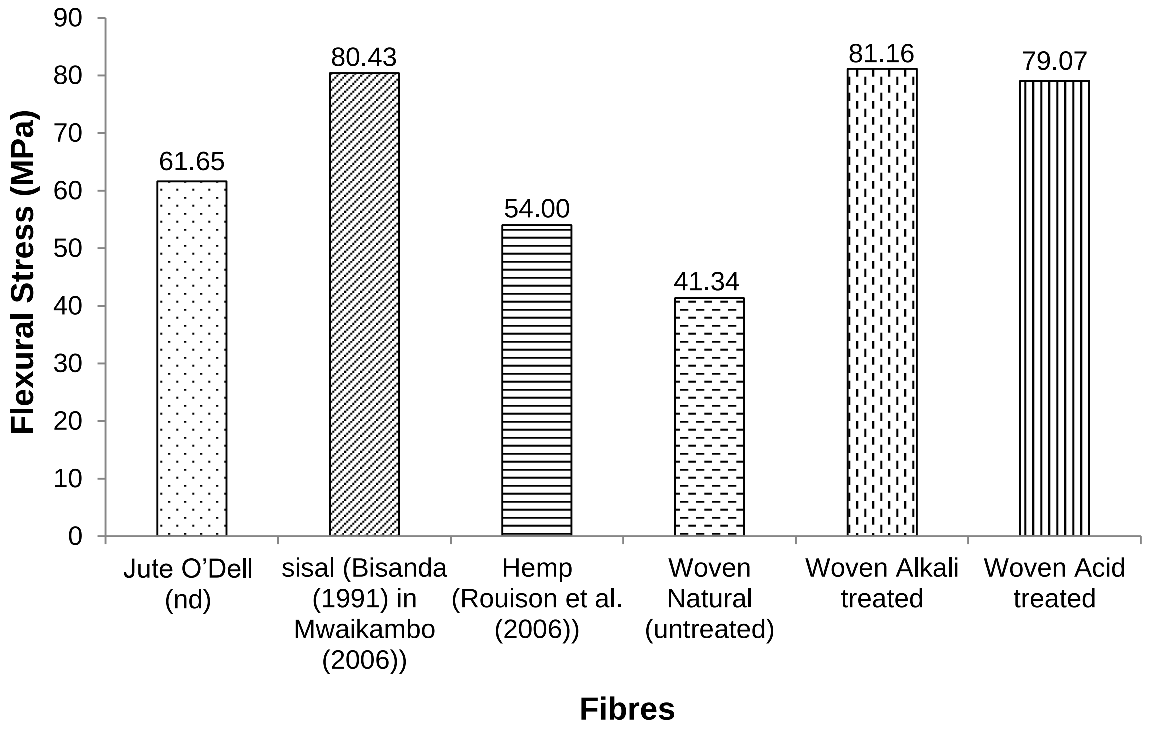
Type of fiber	Density g/cm3	Tensile Strength MPa	Young's Modulus GPs	Elongation at beark %
Cotton	1.5-1.6	287-800	5.5-12.6	7.0-8.0
Jute	1.3-1.45	393-773	13-26.5	1.16-1.5
Flax	1.50	345-1100	27.6	2.7-3.2
Hemp	-	690	-	1.6
Sisal	1.45	468-640	9.4-22.0	3-7
Kenaf	1.4	930	53	1.6
Pineapple	-	413-1627	34.5-82.51	1.6
Coir	1.15	131-175	4-6	15-40
E-glass	2.5	2000-3500	70	2.5
Carbon	1.7	4000	230-240	1.4-1.8

Properties of several natural fibers and E-glass. The values are adopted from the studies and database of [7,19,47–53]. References inside the table are for price only.

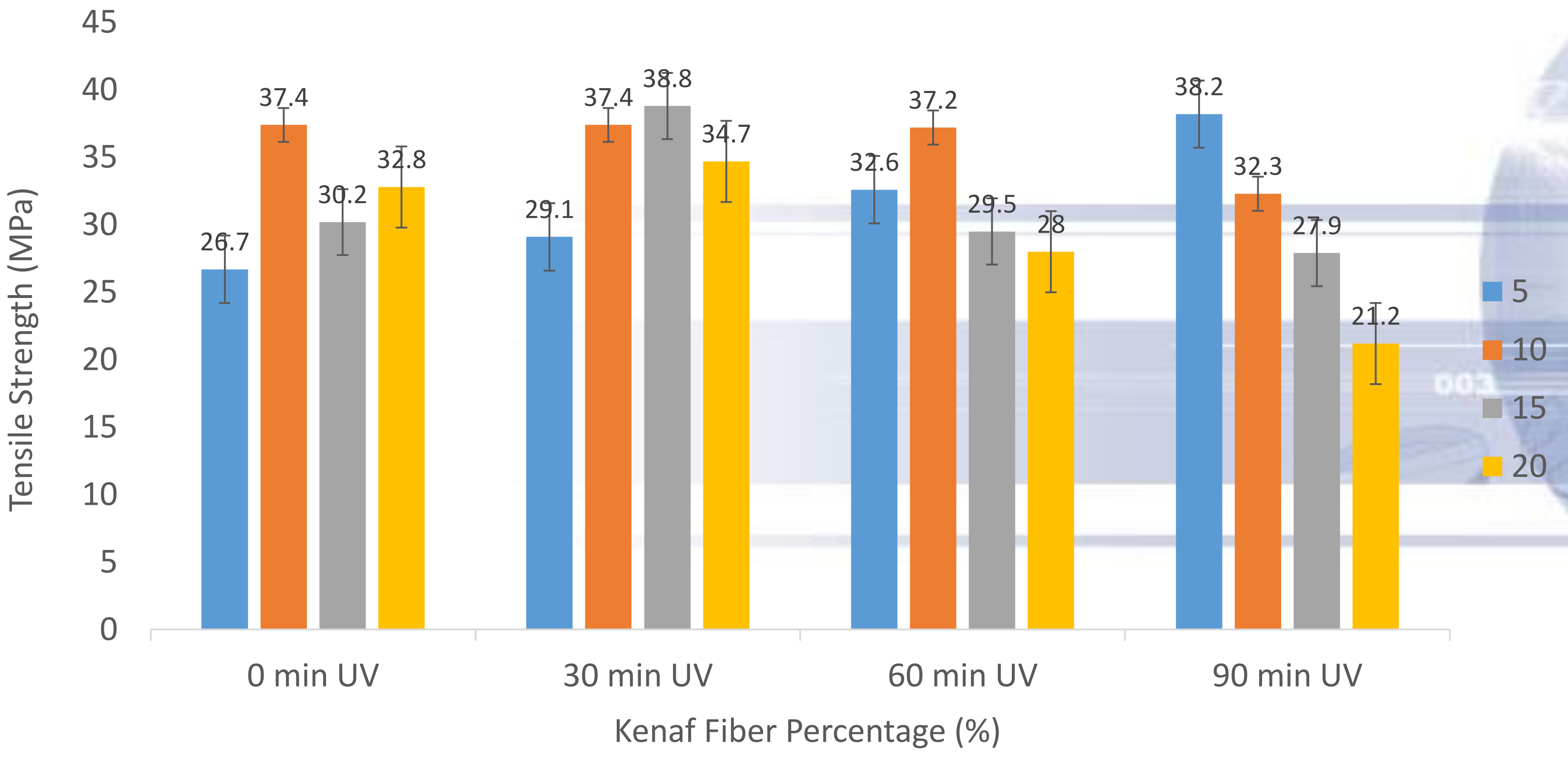
Fibers	Density (g/cm^3)	Diameter (mm)	Tensile strength (MPa)	Young modulus (GPa)	Elongation at brake (%)	Price (USD/kilo)	
Flax	1.5	40–600	345–1500	27–39	2.7–3.2	3.11	[54]
Hemp	1.47	25–250	550–900	38–70	1.6–4	1.55	[54]
Jute	1.3–1.49	25–250	393–800	13–26.5	1.16–1.5	0.925	[54]
Kenaf	1.5–1.6	2.6–4	350–930	40–53	1.6	0.378	[54]
Ramie	1.5–1.6	0.049	400–938	61.4–128	1.2–3.8	2	[54]
Sisal	1.45	50–200	468–700	9.4–22	3–7	0.65	[54]
Curaua	1.4	7–10	500–1100	11.8–30	3.7–4.3	0.45	[55]
Abaca	1.5	10–30	430–813	31.1–33.6	2.9	0.345	[56]
E-glass	2.55	15–25	2000–3500	70–73	2.5–3.7	2	[54]

Performance of Natural Fibers – (Sugar Palm)





Performance of Natural Fibers – (Kenaf)

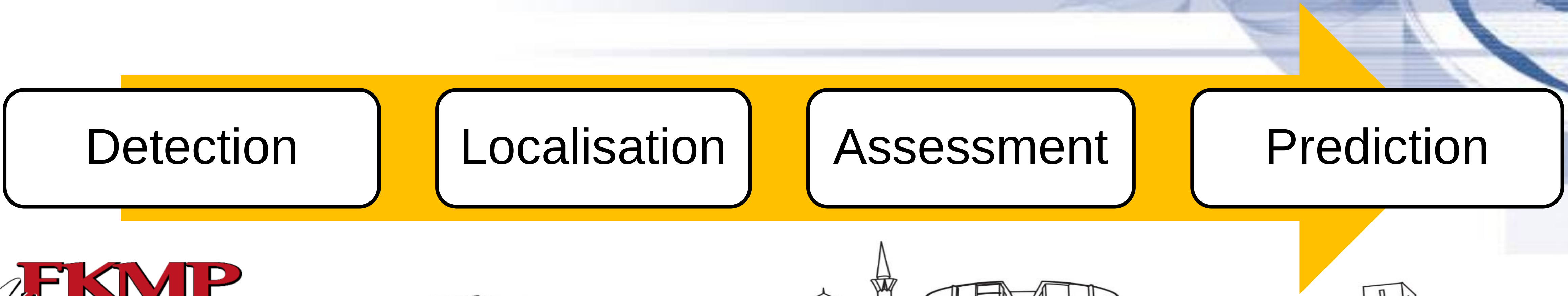


Issues with composites

- **Damage** – consequence of material defect and structural malfunctioning
- Composite materials are more susceptible to **impact** damage than similar metallic structures
- Composite part is subjected to normal **low-velocity** impact of sufficient energy, it may create damage
- Understand the damage involved in the impact of composite targets is important in the effective design of a composite structure.

Structural Health Monitoring

- Structural health monitoring – methodology in evaluating the health of the structure.
- Structural Health Monitoring (SHM) has various interpretation.
  1. "acquisition, validation and analysis of data to facilitate life-cycle management decision" – Perez et.al (2014)
  2. A system that able to detect and interpret adverse changes to improve reliability and reduce life-cycle cost – Farrar and Worden (2007).

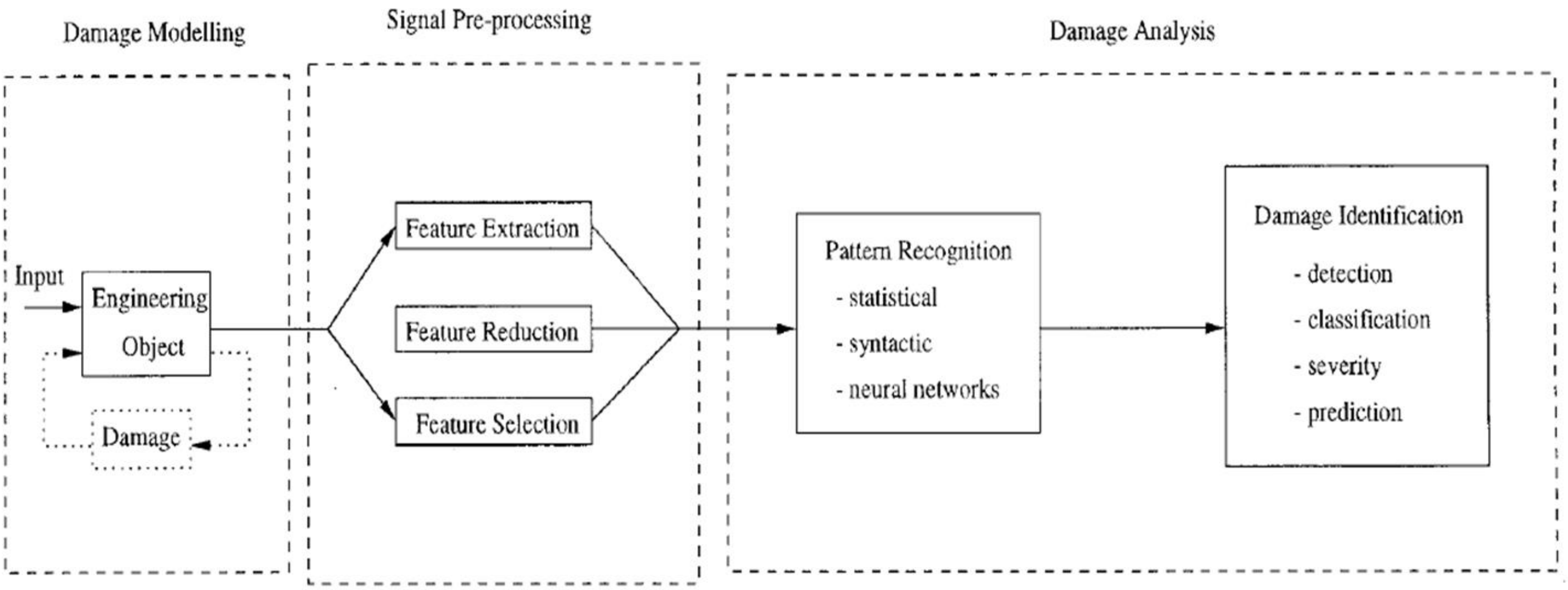


- **Signal processing** and computation are crucial elements in the implementation and operation of any damage identification system.

- The generic system requires the availability of appropriate signal processing technology to **extract features** from different types of sensors and to translate this information into a diagnosis of location and severity of damage.

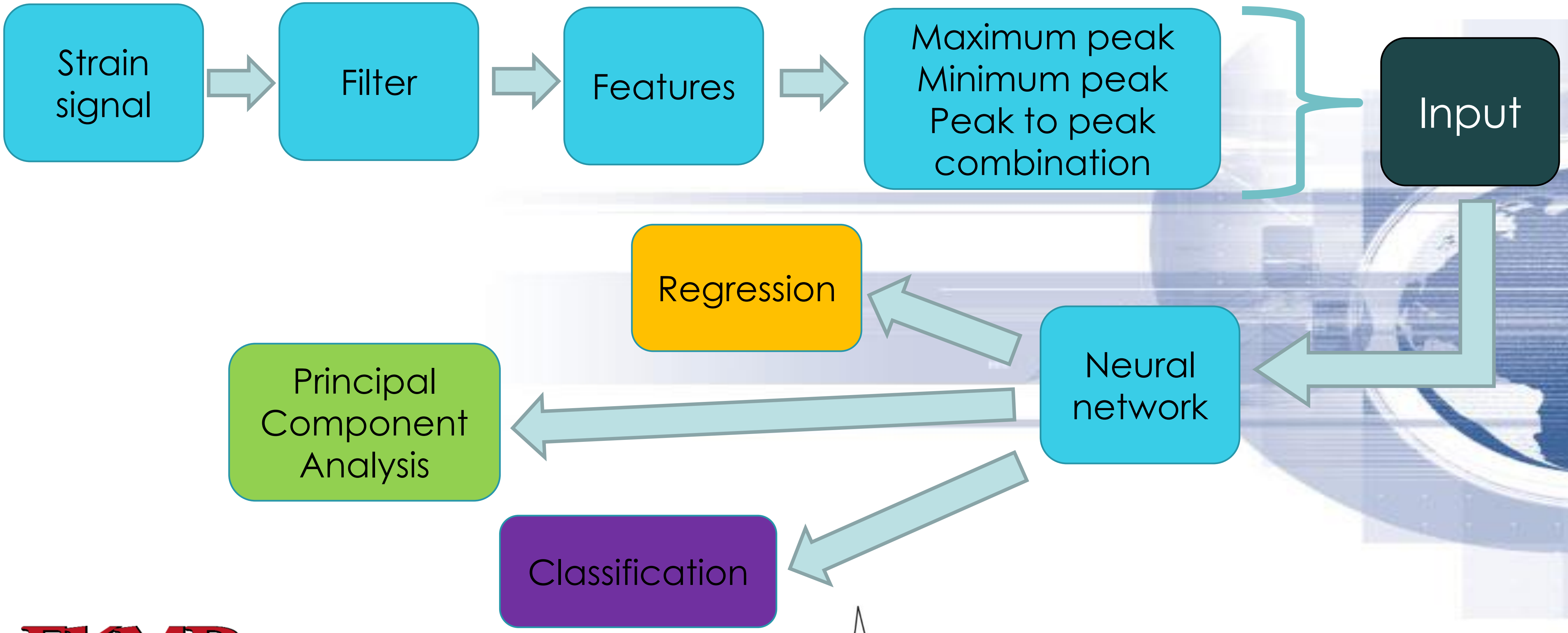
- **Incorporation** between **smart sensors** such as piezoceramic transducers with the damage detection techniques enhancing the signal processing for damage detection.

Strategy

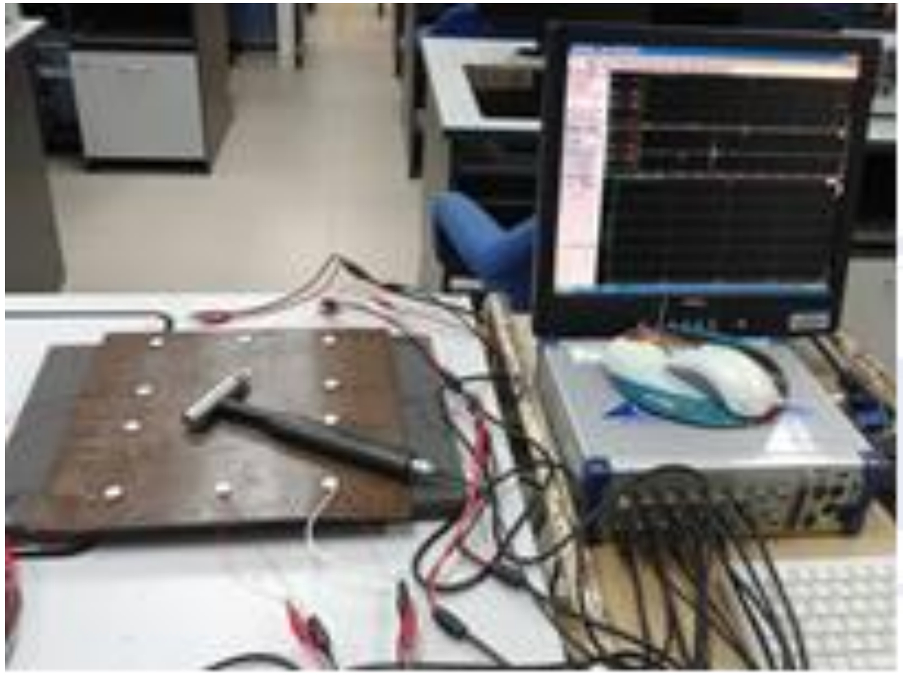


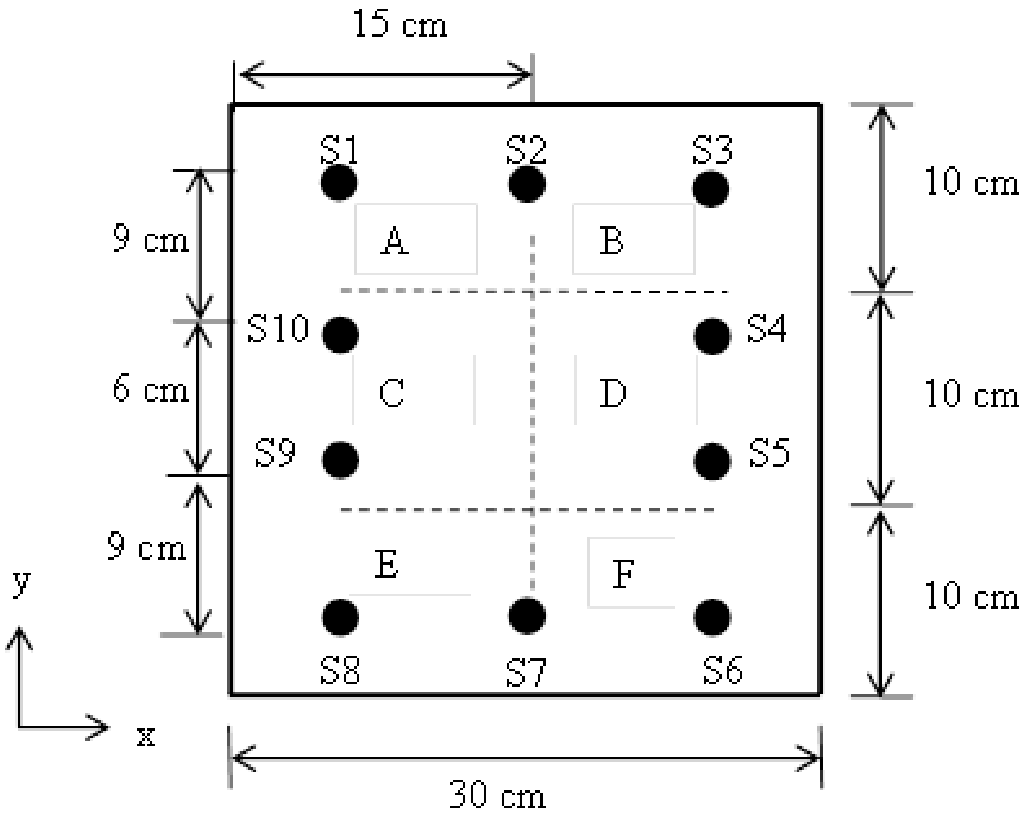
Damage Modelling
Signal Pre-processing
Damage Analysis
Input
Engineering Object
Damage
Feature Extraction
Feature Reduction
Feature Selection
Pattern Recognition
- statistical
- syntactic
- neural networks
Damage Identification
- detection
- classification
- severity
- prediction

Methodology



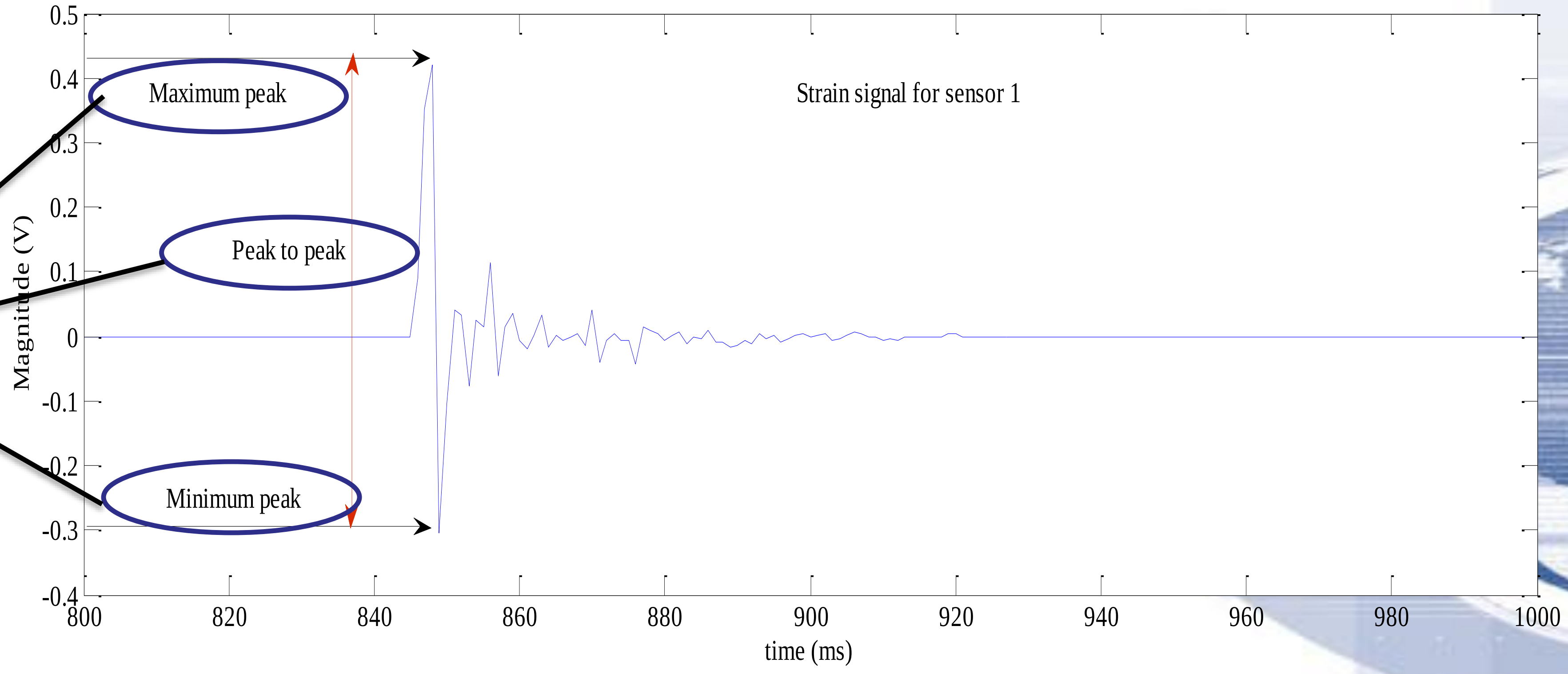
Experimental works



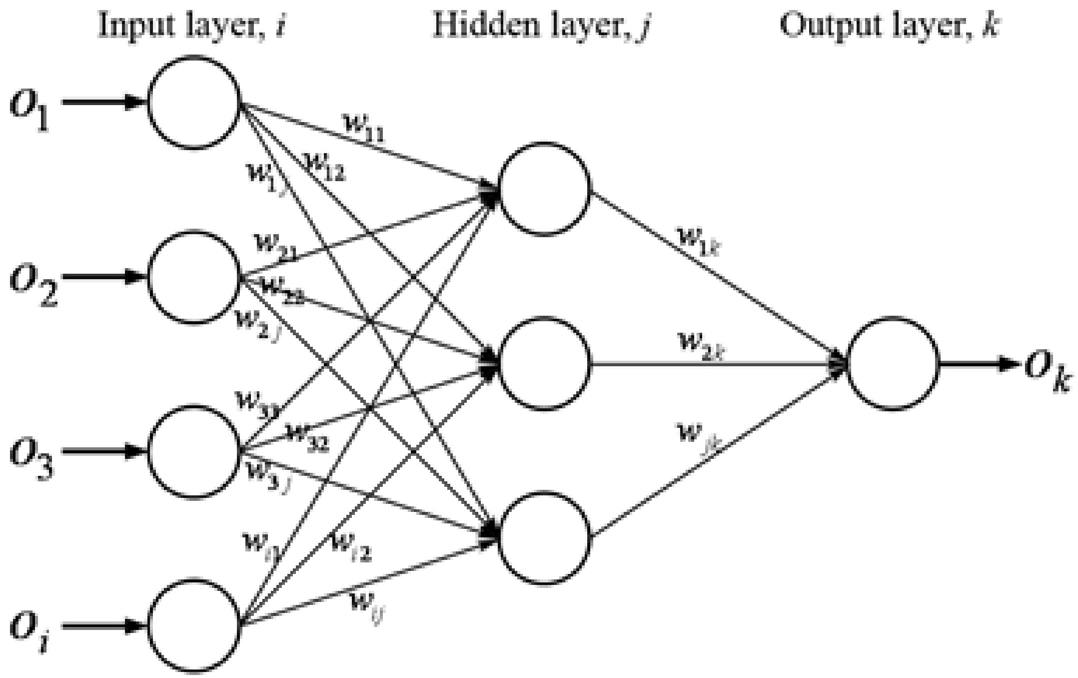


Strain signal

Features Selected

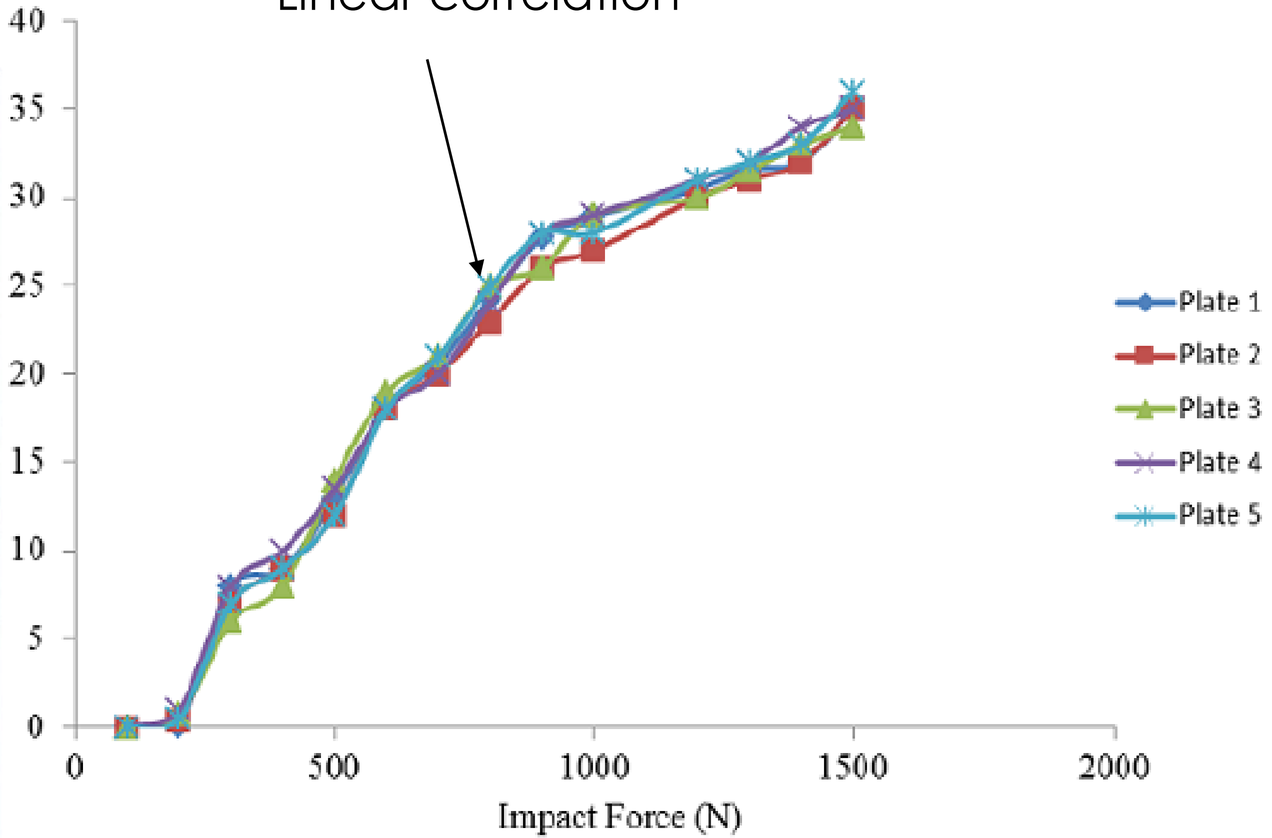


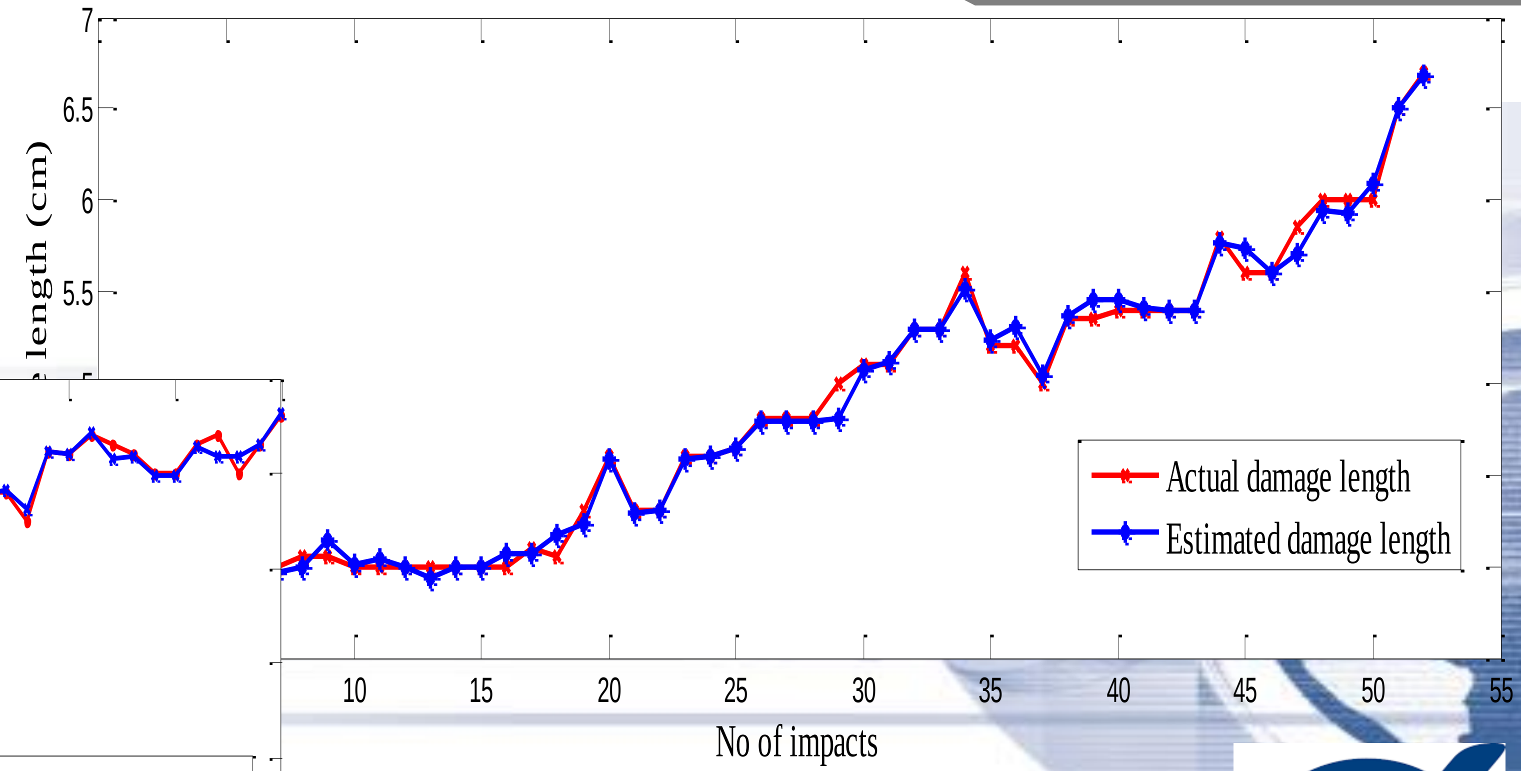
MLP NN

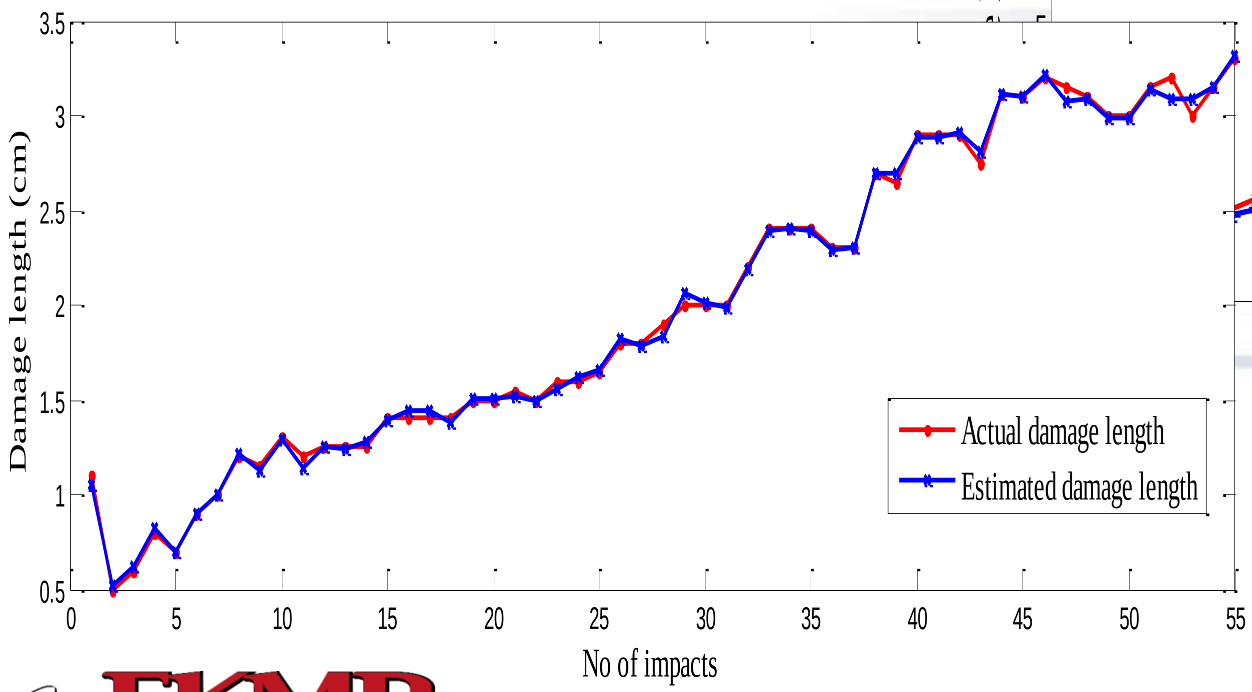


Input layer, i
Hidden layer, j
Output layer, k
O_1
O_2
O_3
O_i
O_k
w_{11}
w_{12}
w_{1j}
w_{21}
w_{22}
w_{2j}
w_{31}
w_{32}
w_{3j}
w_{i1}
w_{i2}
w_{ij}
w_{1k}
w_{2k}
w_{jk}

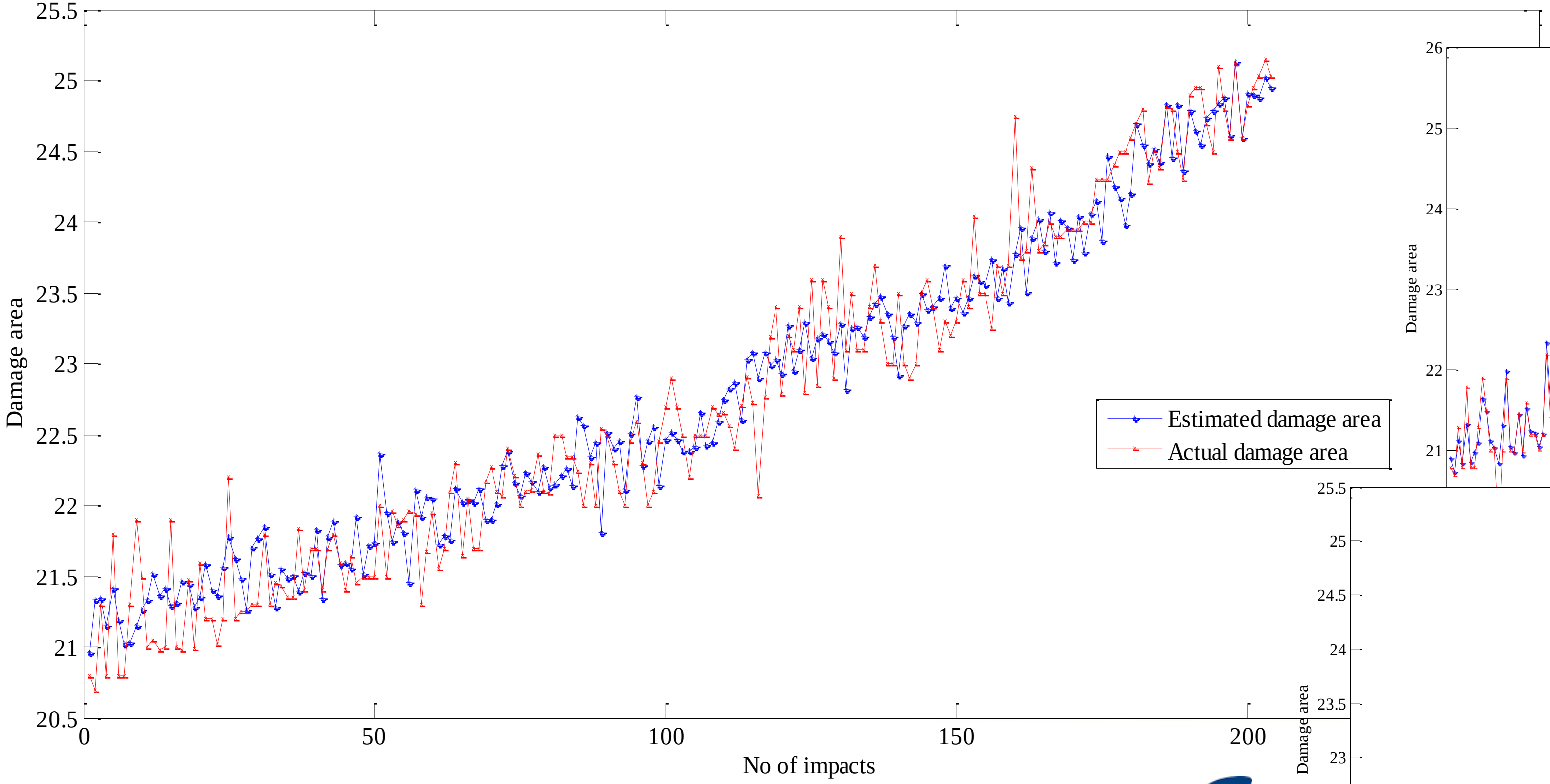
Linear correlation

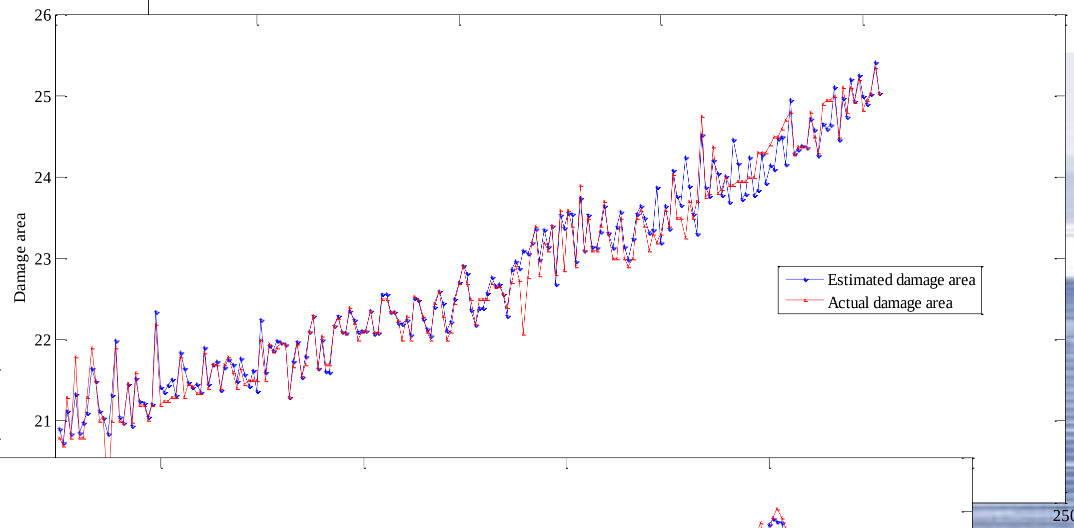


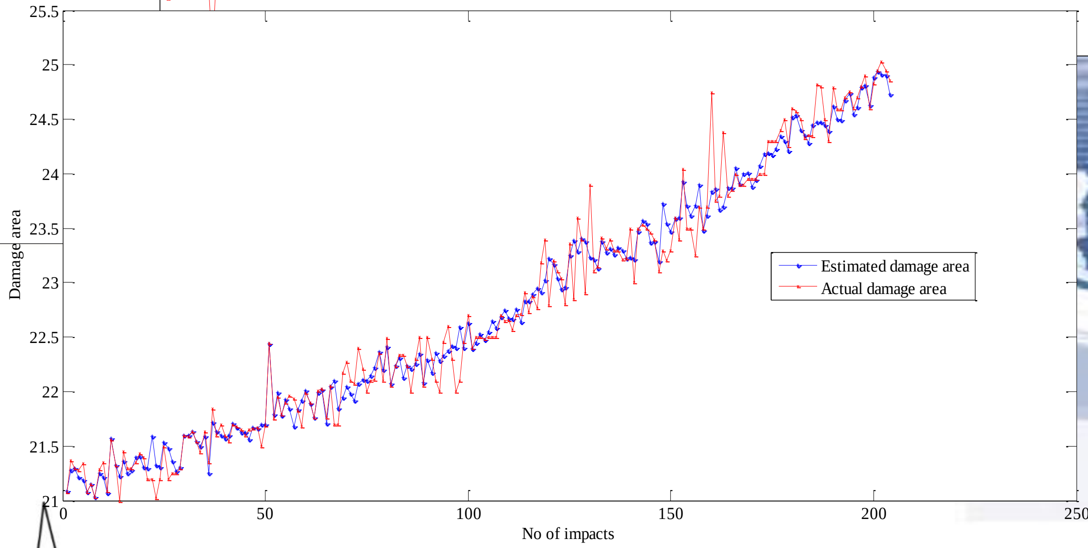




Level 2: Localisation







Level 3: Assessment

Class	Classification of damage
1	No damage/scratches
2	Small cracks
3	Moderate cracks
4	Intermediate Cracks
5	Severe Cracks

Maximum- Classification rate 97.6%

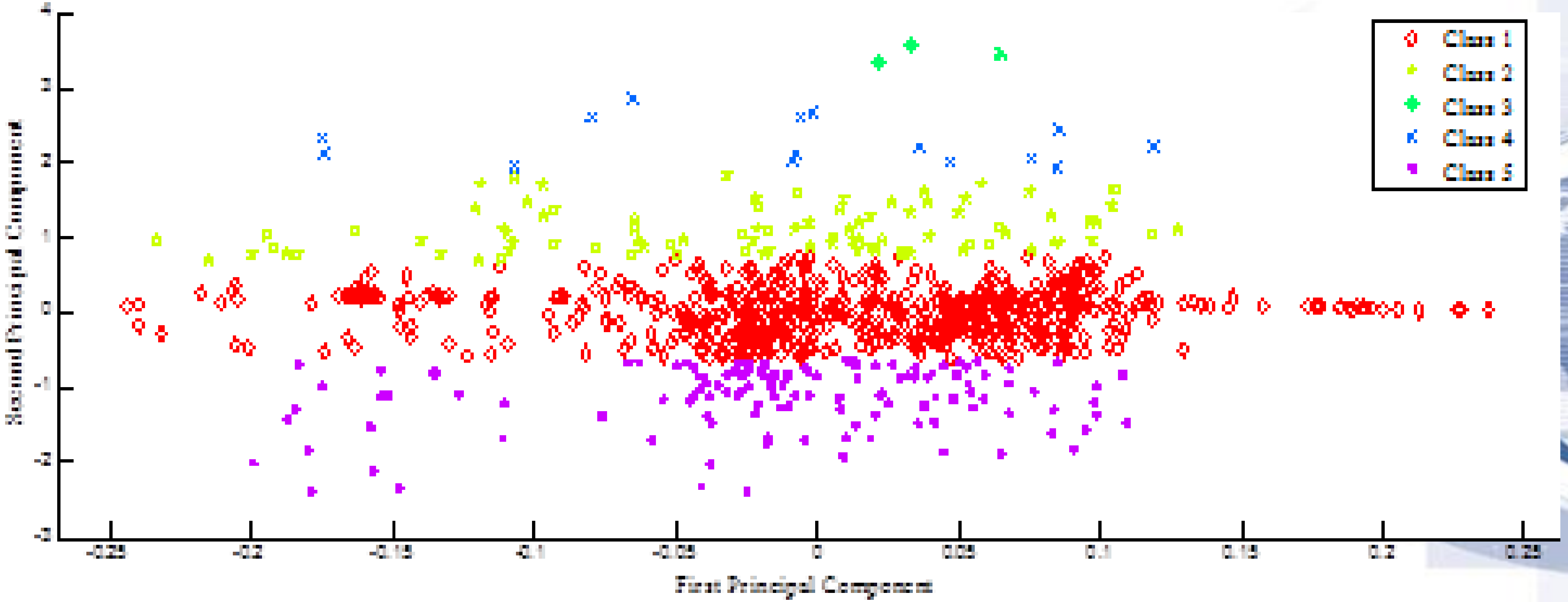
	Predicted Class				
True Class	C1	C2	C3	C4	C5
C1	**98**	2	0	0	0
C2	1	**141**	3	0	0
C3	0	7	**142**	1	0
C4	0	0	5	**353**	1
C5	3	0	0	2	**149**

Minimum- Classification rate 97.9%

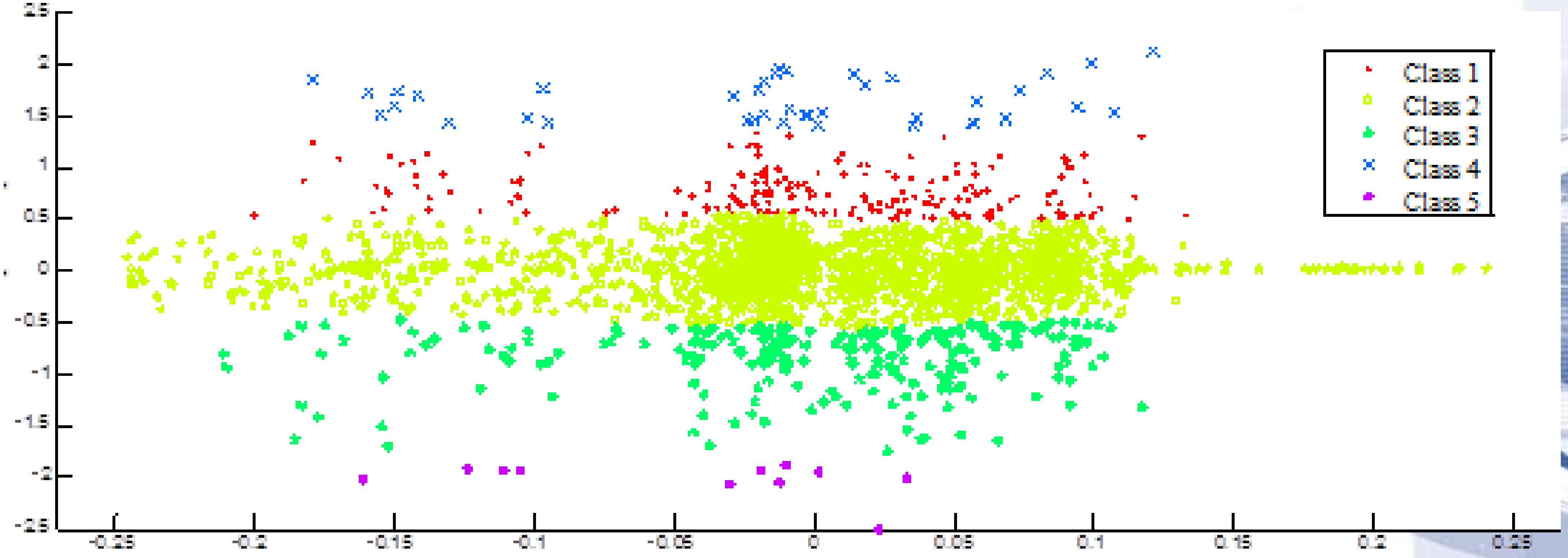
	Predicted Class				
True Class	C1	C2	C3	C4	C5
C1	98	6	0	0	0
C2	1	142	0	0	0
C3	0	2	146	3	0
C4	0	0	4	349	1
C5	3	0	0	2	149

Peak- Classification rate 89.5%

	Predicted Class				
True Class	C1	C2	C3	C4	C5
C1	95	27	0	0	0
C2	4	121	16	0	0
C3	0	2	95	3	0
C4	0	0	39	349	2
C5	3	0	0	5	148



Class 1
Class 2
Class 3
Class 4
Class 5
Second Principal Component
First Principal Component


Class 1
Class 2
Class 3
Class 4
Class 5
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25

Concluding remarks

1. Damage severity of NFC can be solved using impact strain data provided by PZT sensors in terms of passive damage detection procedures.

2. The features obtained from the impact strain data provided consistently results and offer great promise for application in other natural fibre composite.

3. The **Level 1** to **Level 3** in SHM can be used to estimate damage conditions. However, **Level 4** that is prediction need further investigations.

4. Finally, damage severity characteristic and correlation can be explored using signal processing method for NFC.

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Invitation for Collaboration

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