Defect Detection in GFRP Plates Using Electromagnetic Induction Testing Using Autoencoder

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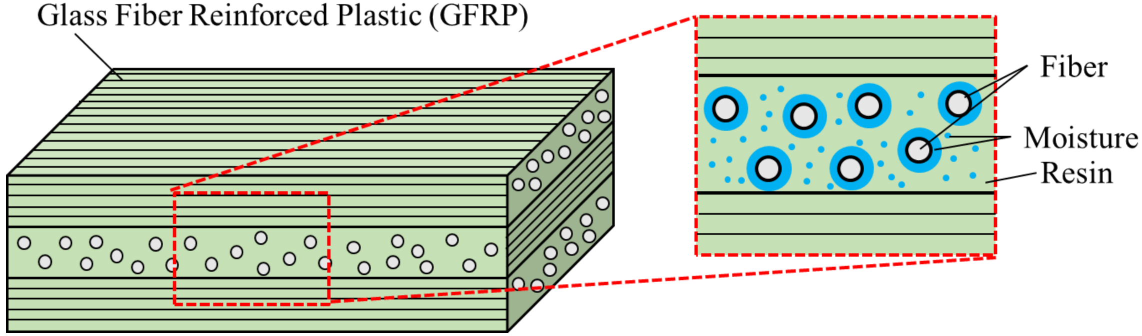
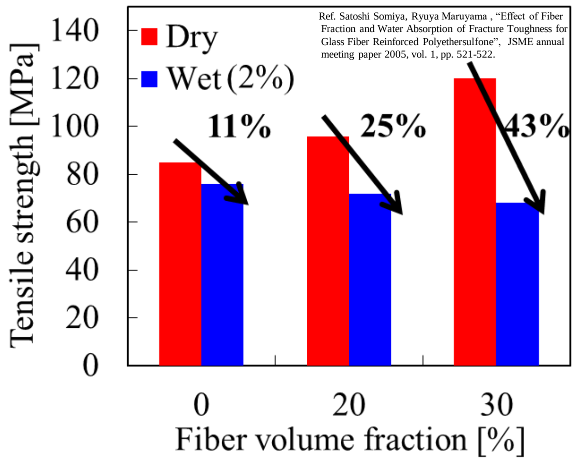
Background (1/2)

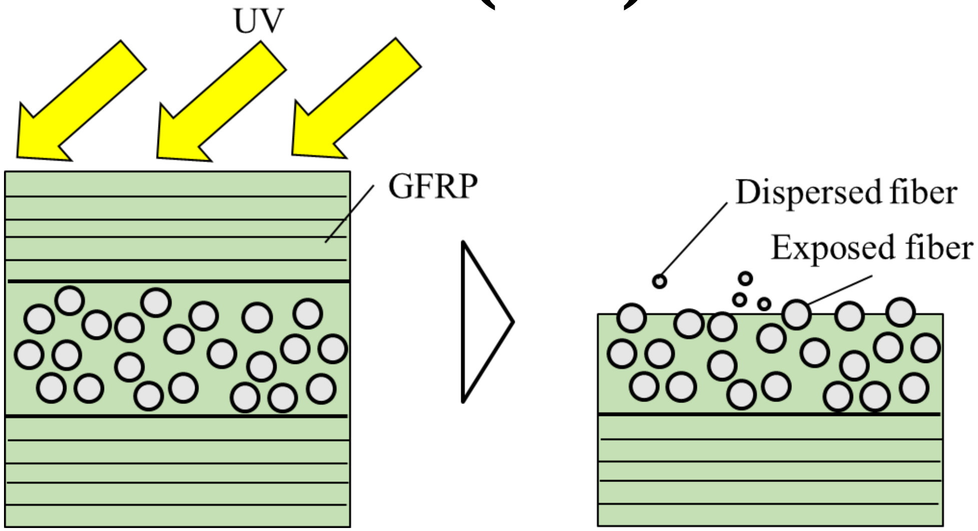
■Moisture absorption



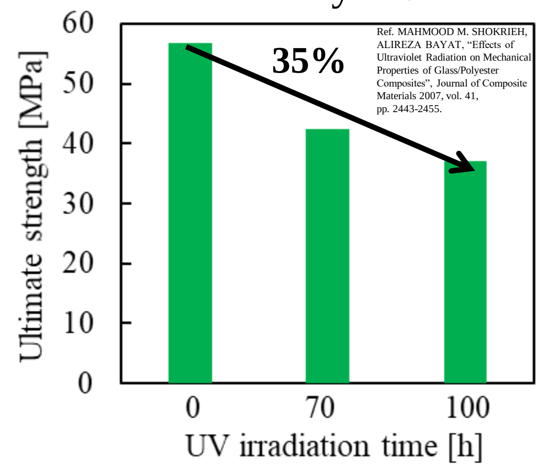
Decrease of the tensile strength in GFRP by moisture absorption



■Ultraviolet (UV)



Decrease of the tensile strength in GFRP by UV



Background (2/2)

■Conventional non-destructive testing method

Ultrasonic Testing (UT)

- Necessity for **couplant**
- Necessity for **speed of sound**

Microwave or Terahertz wave testing

- **Poor spatial resolution**
- **High cost devices**

■Proposal method

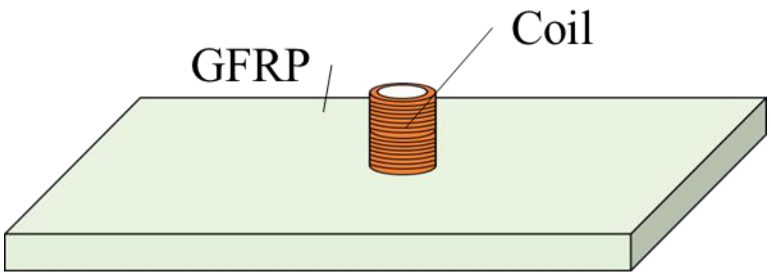
Electromagnetic induction testing (EIT)

- ✓ **High speed** and **no-contact** detection
- ✓ Relatively **low cost devices**
- ✓ **Various spatial resolution** by changing the composition for probe

Objectives

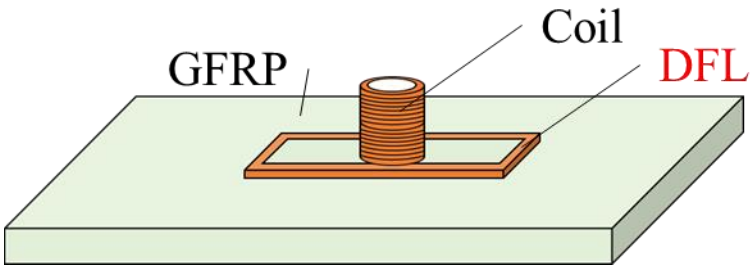
■ Conventional EIT

Applicable to detecting
the crack existence



■ Proposal EIT

Applicable to detecting
the crack opening direction



But…

Interpretation of the experimental results is difficult

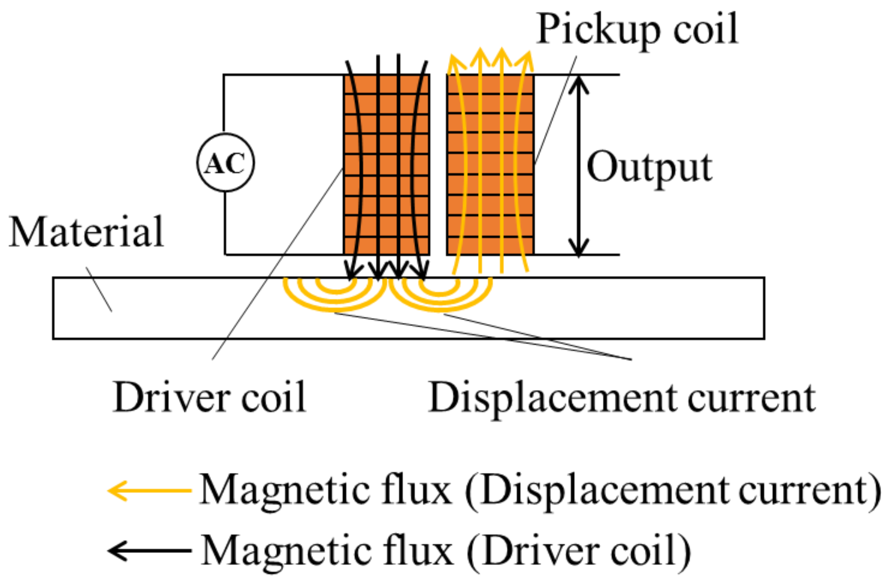
■ Objectives

- Verify the validity of autoencoder for EIT
- Construction of autoencoder which can judge the severe crack orientation

Electromagnetic induction testing (EIT)

■ Principle

- Driver coil
  - ➢ Induce displacement current by applying ac voltage at **high frequency (3-30 MHz)**
- Pickup coil
  - ➢ Detect the change of the electromagnetic field for **displacement current**



Configuration for EIT

■ Advantages for proposal method

✓ Applicable to **non-conductive materials**
✓ **Non-contact** and **high speed detection**
✓ Applicable to **detecting the permittivity**

Proposal method

■ Driver Field Lens (DFL)

AC voltage is applied

▽

Magnetic flux occur and electric-magnetic field is induced into DFL

▽

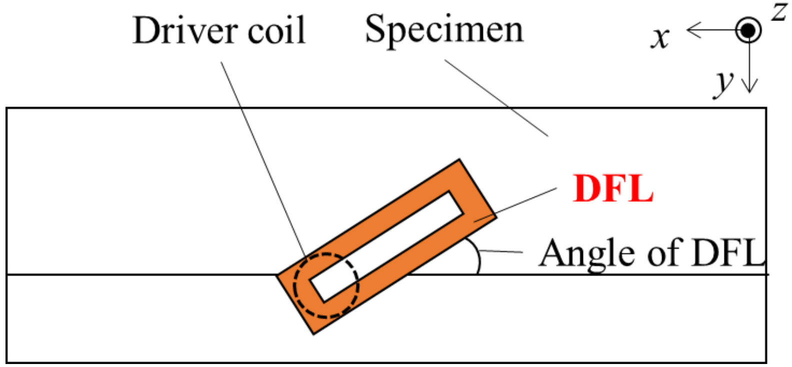
Deform the electromagnetic field

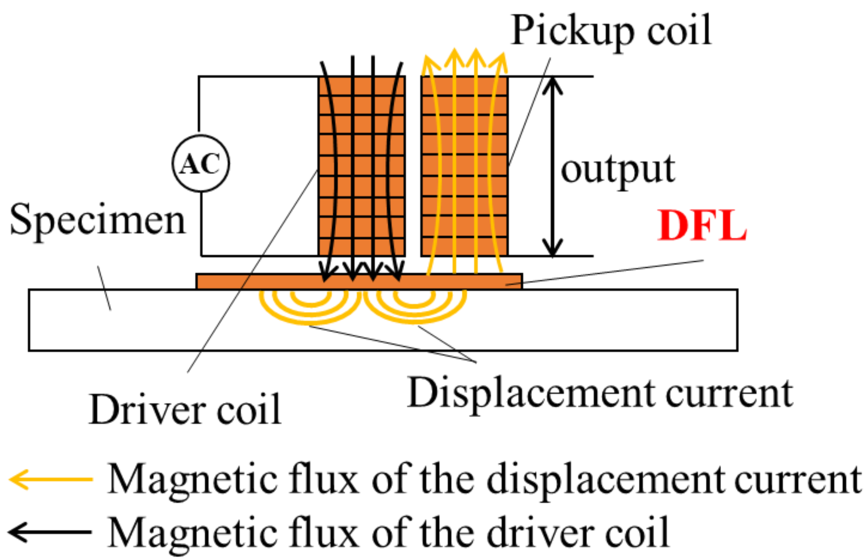
▽

Increase the amount of flux passing through the crack

▽

Detect the angle of crack





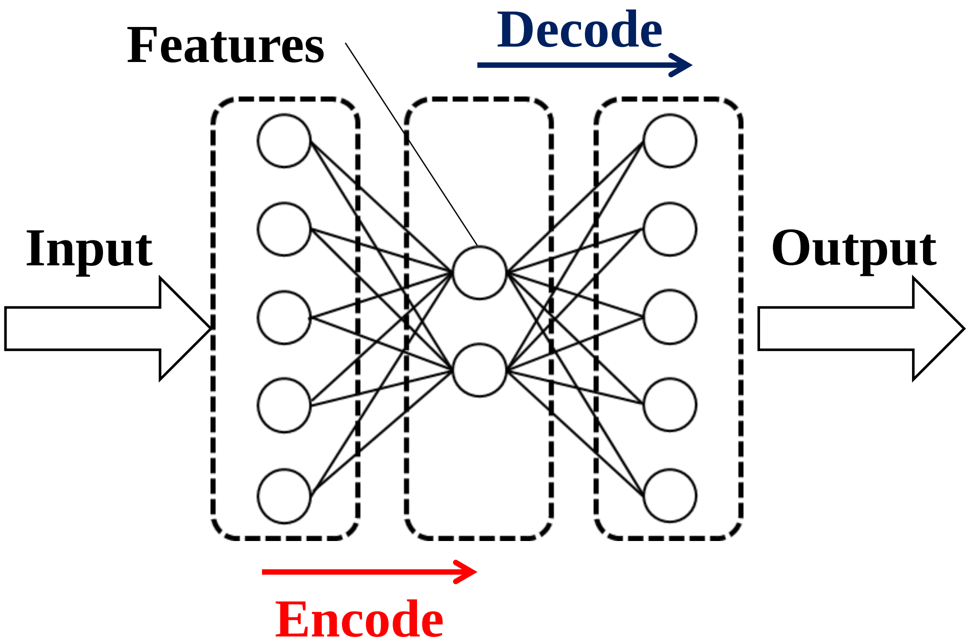
Autoencoder

Autoencoder is composed of **encoder** and **decoder**

■ Encoder

Input data is compressed and dimension of data is reduced

⇨ **Feature** is extracted



Schematic of autoencoder

■ Decoder

Output data is restored using the extracted feature

■ Autoencoder

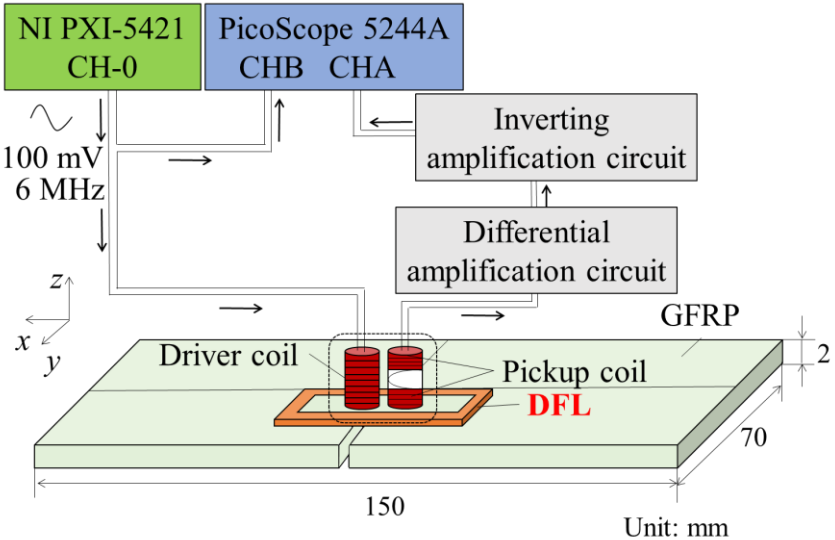
- Training data: data except detection target data
- Input data: some training data and detection target data

⇨ **When the detection target data are input, error is output because the input data cannot decode sufficiently.**

Training data and Evaluation data (1/2)

■ Experiment

- Angle [°]: 0-180 (each 15°)
- Crack width [mm]: 0, 1, 3, 5
- Crack length [mm]: 5, 10, 15, 25
- Detection area [mm]: $-53 \leq x \leq 47$ (each 2 mm)



Schematic for experiment setup

■ Training data: 90° results

Crack length [mm]	Crack width [mm]	DFL angle [°]
20	3	90
45	3	90
35	2	90
35	6	90
20	2	90
20	6	90
45	2	90
45	6	90

Crack length [mm]	Crack width [mm]	DFL angle [°]
35	1	90
35	3	90
35	5	90
5	1	90
10	1	90
15	1	90
25	1	90
0	0	90

Training data and Evaluation data (2/2)

■ Evaluation data: except for 90° results

Crack length [mm]	Crack width [mm]	DFL angle [°]
35	1	0, 15, 30, 45, 60, 75, 105, 120, 135, 150, 165, 180
35	3	0, 15, 30, 45, 60, 75, 105, 120, 135, 150, 165, 180
35	5	0, 15, 30, 45, 60, 75, 105, 120, 135, 150, 165, 180
5	1	0, 15, 30, 45, 60, 75, 105, 120, 135, 150, 165, 180
10	1	0, 15, 30, 45, 60, 75, 105, 120, 135, 150, 165, 180
15	1	0, 15, 30, 45, 60, 75, 105, 120, 135, 150, 165, 180
25	1	0, 15, 30, 45, 60, 75, 105, 120, 135, 150, 165, 180
0	0	0, 15, 30, 45, 60, 75, 105, 120, 135, 150, 165, 180

Crack length [mm]	Crack width [mm]	DFL angle [°]
20	3	60, 210
45	3	60, 80, 210
35	2	60, 80, 210
35	6	60, 80, 210
35	3	80, 110, 210, 270
20	6	80, 210
45	2	80, 210
45	6	80, 210

When the 90° results are inputted

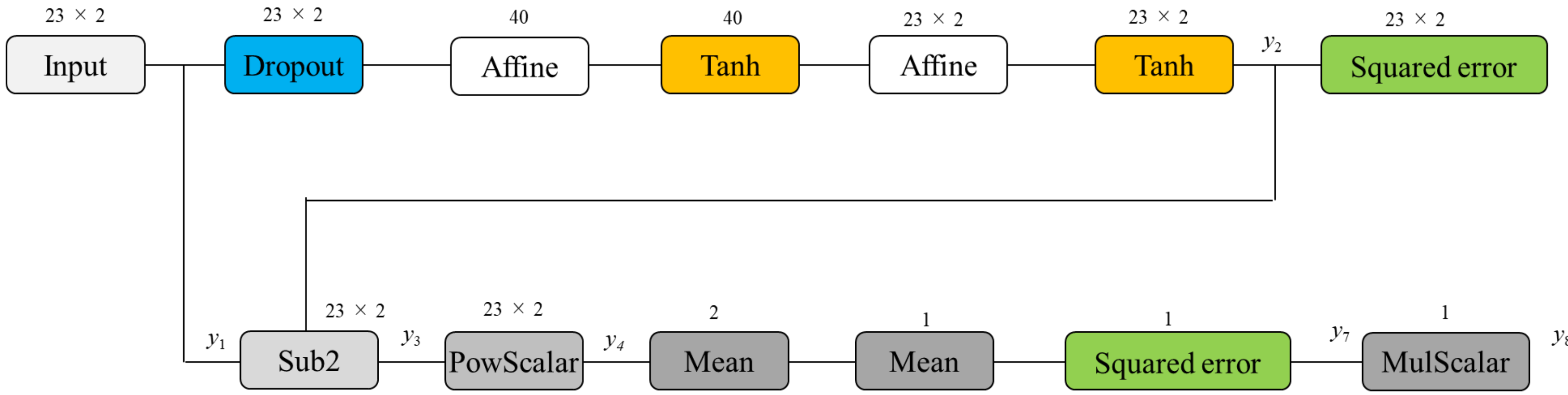
⇨ **Normal** (low error value)

When the other degree results are inputted

⇨ **Anomaly** (high error value)

Architecture of autoencoder

■ Constructed autoencoder



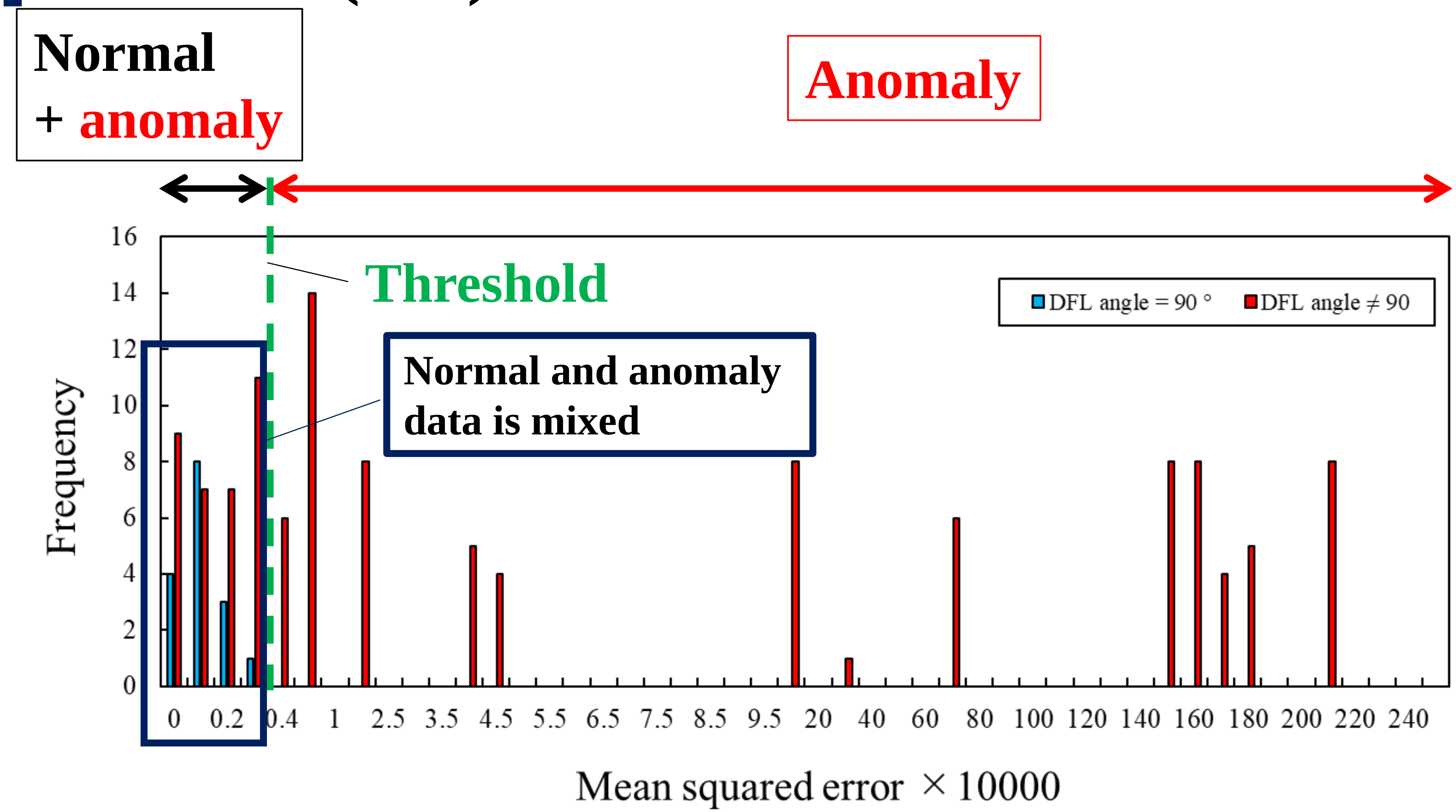
Architecture of autoencoder

- Input data (-1 ≤ Value ≤1)
  Normalization
  $$V_{\text{n-in}} = V_{\text{in}} / 70$$
  $$V_{\text{n-out}} = V_{\text{out}} / 2500$$
- Tanh: activation function
  Hyperbolic tangent function
- PowScalar: $y_4 = y_3^2$

- Sub2:
  $$y_3 = y_1 - y_2$$
- MulScaler
  $$y_8 = y_7 \times *$$

In this autoencoder, * = 0 due to eliminating the effect of the squared error

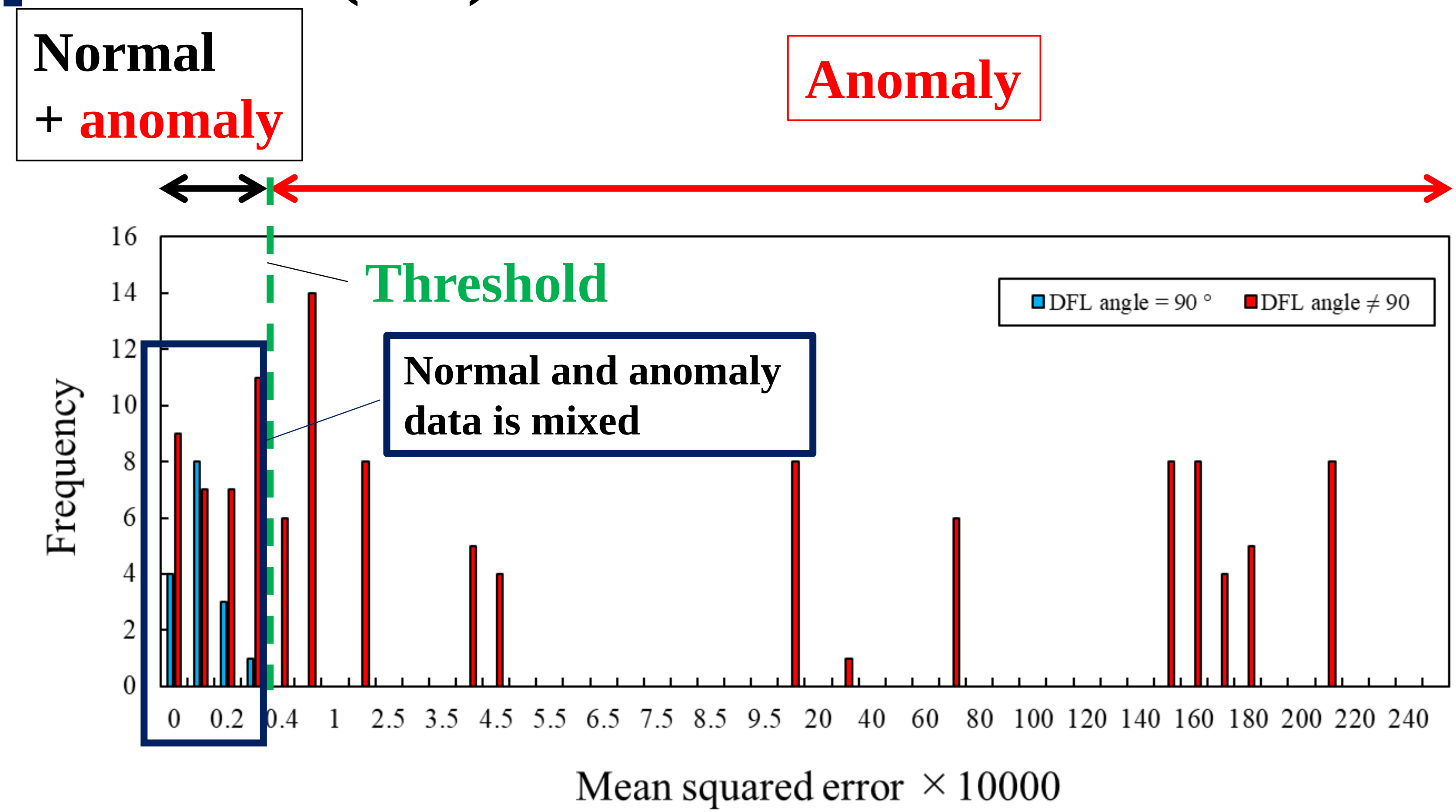
Results (1/2)



Error for the anomaly data is distributed wider range

⇨ **This results cannot be divided into two groups simply because the normal and anomaly data is mixed in specific error range**

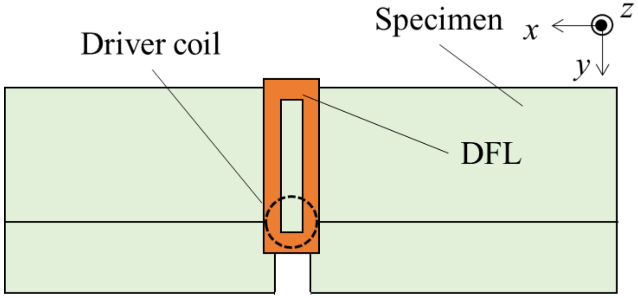
Results (2/2)



- Error for the normal data is small while anomaly data is large
- Error for the normal data is distributed in smaller range

⇨ **Separate the data not including the normal data from the data including normal data by setting the appropriate threshold**

Discussion

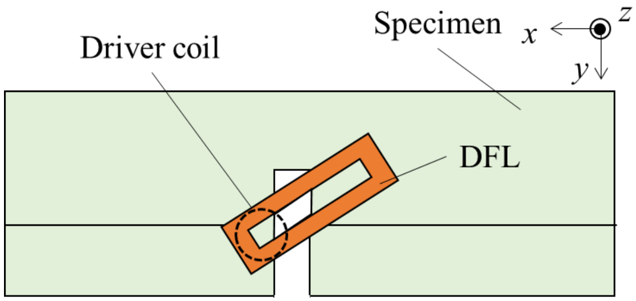


- **Normal data:**

No crack and 90° data

(DFL angle = Crack angle)

⇨ Severe crack data + without crack data



- **Anomaly data:**

No crack data and data except for 90°

(DFL angle ≠ Crack angle)

⇨ Non-severe crack data + without crack data

- **Total data: normal data + anomaly data**

⇨ Severe crack data + non-severe crack data + without crack data

This method is applicable to first screening to separate the severe crack data

Conclusion

- The validity of autoencoder for electromagnetic induction testing is demonstrated.

- The constructed autoencoder cannot divide into normal and anomaly data because these data are mixed in the specific error range.

- The constructed autoencoder can separate the data not including the normal data from the data including normal data by setting the appropriate threshold.

  ⇨ The constructed autoencoder is valid for first screening to separate the severe crack data.

Thank you for your attention