ESTIMATION OF NONLINEAR PIESO RESISTANCE BEHAVIOR OF 3D PRINTED COMPOSITES USING ARTIFICIAL NEURAL NETWORK

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Introduction

Additional sensors such as strain sensors and fiber optic sensors [1] can be used for structural health monitoring. one of the health monitoring methods for CFRP is the electrical resistance change method. This method monitors changes in the electrical resistance itself and thus does not require additional sensors. In addition, it is an inexpensive and simple method because it only involves creating electrodes and measuring the electrical resistance. In the conventional CFRP made by prepreg, the behavior of change in electrical resistance is linear [2]. In addition, it can detect strain and defects such as delamination and fiber breakage [3]. However, the application of the electrical resistance change method on 3D printed CFRP revealed that the behavior of the electrical resistance change is nonlinear [4]. The monitoring of integrity on 3D printed CFRP is difficult due to the nonlinear behavior. It needs to estimate the nonlinear behavior.
Artificial neural network (ANN) is attracting attention as a means of estimation of sensing data [5]. B. Oldfrey et al. [5] applied an ANN to enable sensing by the nonlinear behavior of wearable flexible sensors, since their behavior is nonlinear with respect to strain, and showed its effectiveness.
Therefore, it is possible to estimate the nonlinear data. Although ANN can be used to estimate nonlinear sensing data, however, it has not been clarified whether they can estimate the behavior of electrical resistance change of 3D printed CFRP, which shows more complex behavior.
In this study, the aim of this study is to predict the nonlinear behavior of change in electrical resistance of 3D printed CFRP using artificial neural network.

Artificial neural network

The flowchart of this study is shown Fig.1. As a first step, cyclic tensile tests were performed to acquire data. The data includes electrical resistance, stress, strain, and time. The change in electrical resistance is the difference between the measured electrical resistance and the original electrical resistance divided by the original electrical resistance. The change in electrical resistance is nonlinear behavior compared with stress, strain, and time during cyclic tensile test [4]. In order to monitor the applied stress on 3D printed CFPR using electrical resistance change method, it is necessary to estimate the stresses from this nonlinear behavior. For this reason, we decided to use an artificial neural network to estimate the stress from the electrical resistance change. As a second step, we decided on the data to be used for the ANN. Train data and validation data included change in electrical resistance, applied stress, and time and change in electrical resistance history. A data set was created to simulate actual monitoring, and the stresses imposed on the 3D printed CFRP were predicted. Convolution neural network (CNN) and recurrent neural network (RNN) was used as an ANN model for estimation of change in electrical resistance.

Estimation of applied stress using ANN

Fig. 2 shows predicted stress for CNN and RNN. The predicted stresses were evaluated qualitatively and quantitatively, and both predicted stresses showed good agreement. The correlation coefficient was used for qualitative evaluation. The correlation coefficient is 0.83 for CNN and 0.92 for RNN. Both qualitative results show a good positive correlation. For quantitative evaluation, the error from

each estimated stress was confirmed. For quantitative evaluation, the error from each estimated stress was checked; the stresses that could be estimated within 5% error were 24.8% for CNN and 44.7% for RNN. When the error was 20%, the error was 70.8% for CNN and 92.9% for RNN. This means that RNN can provide better qualitative and quantitative stress estimation than CNN, indicating the possibility of implementing stress estimation from nonlinear piezoresistive behavior.

Conclusions

In order to monitor the structural health of 3D printed CFRP by piezoresistive change, we tried to estimate the stress from nonlinear data by using ANN. We verified whether CNN and RNN can be used to estimate stress from nonlinear data, and showed that qualitative and quantitative estimation is possible. It was also shown that RNN can provide better qualitative and quantitative stress estimation than CNN, indicating the possibility of implementing stress estimation from nonlinear piezoresistive behavior.

References

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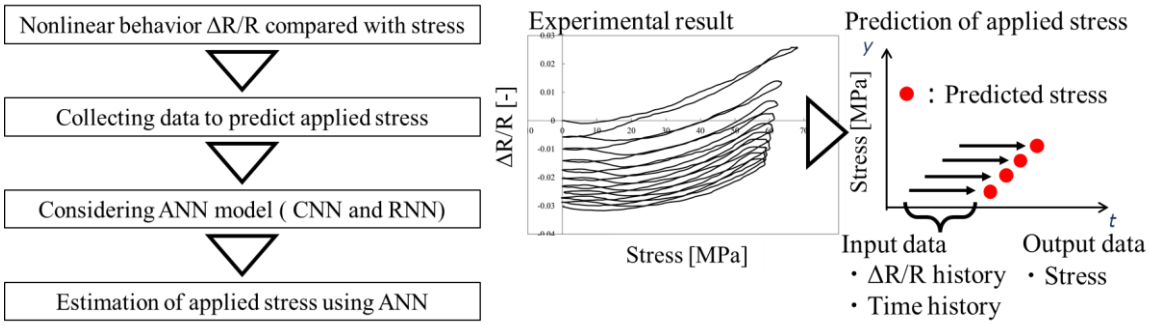
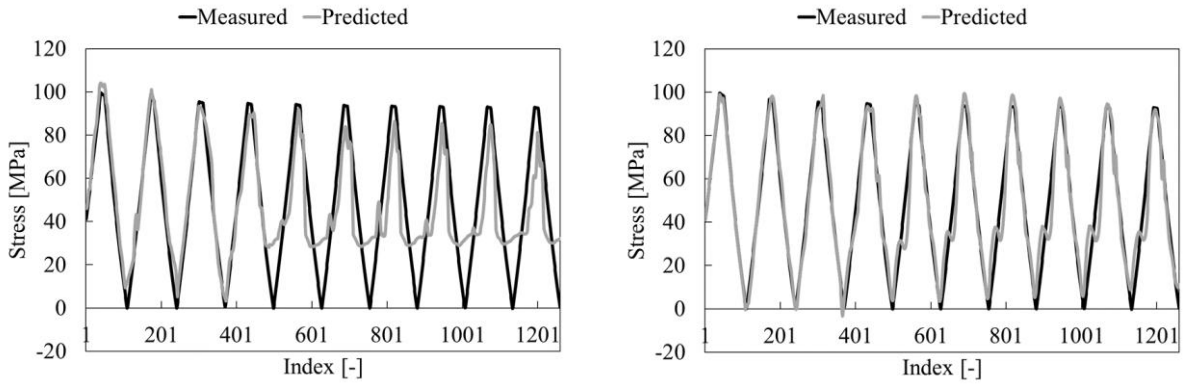


Fig. 1 – Flowchart of this study



(a) Prediction for CNN

(b) Prediction for RNN

Fig. 2 Estimated stress using CNN and RNN