Method for Measuring the Risk Level of Structures Using PMC Smart Sensors

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1. Introduction

Collapse of the engineering structure is a terrible disaster that not only causes massive property damage but also casualties. Already engineering structures such as bridges, buildings, airplanes, and railways are closely related to our lives. Therefore, the structural health monitoring (SHM) technology is a must-have technology to be aware of the damage of engineering structures in advance. Many structural health monitoring technologies are being studied to identify the signs of collapse that occur before an accident.

Among them, the use of smart sensor technology using PMCs is increasing. Smart sensors that use PMC have characteristics that are controllable in mechanoelectrical properties. As structures change, resistance changes in sensing element will occur and a method that monitors these characteristics is usually adopted [1]. Unlike conventional sensors that are difficult to apply to round structures, smart sensor can be applied to different types of engineering structures according to the fabrication method. However, the structure management technology currently being studied using PMCs is only at the level of monitoring the deformation of a structure using a single sensing element. These technologies have the problem of not able to predict when a structure needs maintenance or how long its life span remains. To effectively manage a structure and prevent accidents before they occur, it is imperative that a method to distinguish risks step by step through the strain of a structure.

In this study, a method is proposed to measure the risk level of engineering structures using PMCs. This method has the following characteristics. First, this method uses the sensing element by using PMC that can control mechanoelectrical properties. Second, this method used sensing elements should be three or more to distinguish between risk levels. Third, the used sensing elements have the different mechanoelectrical properties of each sensing element. Finally, this method can detect the change in resistance of sensing elements with different mechanoelectrical properties that enables the classification of risk levels according to changes in deformation behavior of structures.

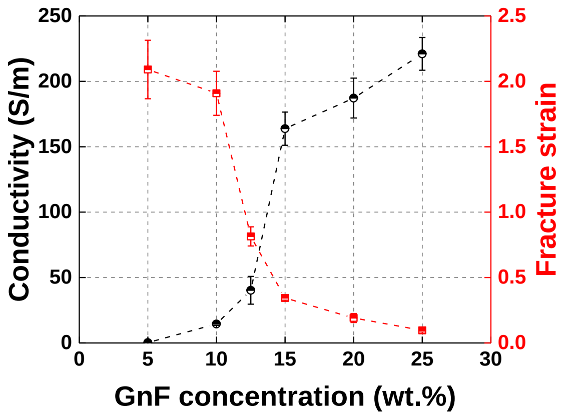
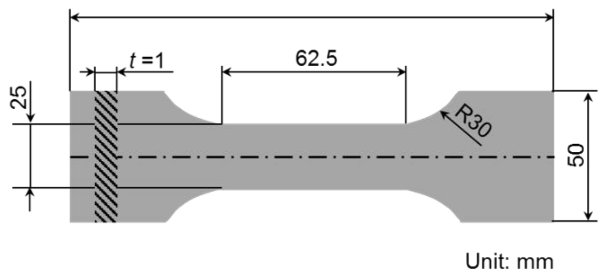


Fig. 1 Conductivity and fracture strain vs. GnF concentration.

2. Materials and methods

The PMC was made using polydimethylsiloxane (PDMS) as an elastic host matrix and graphite nano flake (GnF) as a conductive filler. The GnF/PDMS composite's mechanoelectrical properties was characterized by controlling the concentration of GnF in the composite (as shown Fig. 1) [2]. The GnF/PDMS sensor was made by spraying method [3]. GnF/PDMS composite on the surface of a stainless-steel plate (SUS 304)



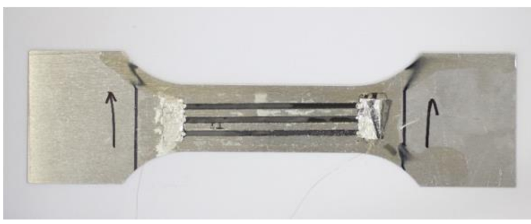


Fig. 2 Specimen design: ISO 6892-1 specimen dimension (top), SUS 304 specimen with sensing elements (bottom).

which was machined into dog bone shape according to the standard for tensile test, ISO 6892-1, as shown in Fig. 2. The sensor was composed of three sensing elements with different GnF concentration which were 25 wt%, 20 wt%, and 15 wt% (1st, 2nd, 3rd sensing elements respectively). These sensing elements were chosen to ensure that they were fracture. Based on the fracture strain value of the sus 304 takes place below 0.6, the correction with values lower than the strain value of 0.5 was selected.

The specimen with sensing elements were tensile tested using Instron 5500 universal testing machine (Instron, USA) and the resistance of the GnF/PDMs sensor was measured using 34401A multimeter (Keysight Technologies, UK) during the tensile test to observe the resistance change according to strain rate because the sensor also stretched with the stainless specimen.

3. Results and discussion

As shown in Fig. 3, the fracture points, where there is a rapid change in resistance, of three elements during the tensile test are different. At the beginning, the resistance of the sensor was continuously increased during tensile test before the fracture of 1st sensing element was occurred at the strain of 0.38. In that point the resistance was instantaneously increased. The fracture of 2nd sensing element was occurred at 0.42 and the 3rd one was 0.95 which was the same point that the fracture of specimen was occurred.

This result was achieved because of the GnF concentration affected the mechanoelectrical property of GnF/PDMS composites. As the GnF concentration increases the elastic modulus and the resistance of the GnF/PDMS. For this reason, the 1st sensing element, which has the highest GnF concentration of 25 wt%, was fractured at first and showed significant resistance change. The

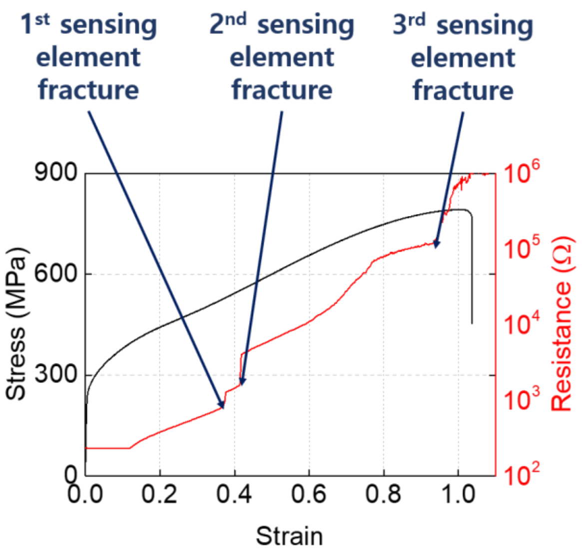


Fig. 3 A stress-strain curve of the specimen with resistance change of the GnF/PDMS sensor.

fracture of 1st sensing element notified the beginning of deformation of specimen, the 2nd element fracture reported preliminary sign of fracture, and finally the 3rd element fracture reported the permanent fracture of the specimen.

Applying this result, we can develop a GnF/PDMS sensor that can detect not only the fracture of structure, but also the preliminary sign of fracture and moreover, behavior of structure after fracture. The phases of fracture can be detected in more details if we use more sensing elements.

4. Conclusion

In this study, we proposed a SHM method using PMCs sensor that can detect not only the moment of fracture of structure but also signs of fracture and post behaviors of fractured structure by sensing structural deformation. The proposed PMCs (GnF/PDMS composites) sensor uses three sensing elements with different GnF concentration. Because the mechanoelectrical property of GnF/PDMS composites can be controlled by controlling GnF concentration, the proposed sensor can detect specific phases in fracture of the structure. As an example, we can adjust the GnF concentrations to detect the elastic deformation region, plastic deformation region, and fracture point of structure. The study is expected to help in developing a new SHM system that can predict and prevent fracture of structures by classifying the deformation of structure step by step.

Acknowledgment

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