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Fundamental Study on Health Monitoring of Steel Structures by Strain Sensor Functioned with Carbon Particle-Polymer Composites

Tadashi Fujisaki
Special Projects Department, Institute of Technology, Shimizu Corporation
4-17, Etchujima 3-Chome, Koto-ku, Tokyo 135-8530, Japan
Fax: 81-3-3820-5959, e-mail: fujit@sit.shimz.co.jp

Study on health monitoring system of steel structures by strain sensor functioned with carbon particle-polymer composites was put into operation. The strain sensor was made on a PET film by printing carbon particles. The sensor had a unique characteristic. Namely, a linear relation holds between logarithm of electric resistance and elongation. The characteristic of the strain sensors, which were stuck on steel plates or H shape steel, was examined. From the results of tension test on the steel plates, it was found that we can presume the recorded maximum strain from the remained electric resistance. However, from the results of alternate bending test on the H shape steel, it turned out that the remained electric resistance depending on compressive strain is different from that depending on tensile strain. The problem to resolve remained about presuming the recorded maximum strain from the remained electric resistance of the strain sensor.

Key words: Carbon particle, Electric resistance, Strain sensor, Steel structure, Health monitoring

1. INTRODUCTION

Research and development on grasping the damage of structural members using the change of electric resistance of carbon has recently begun. This technology utilizes the electric conductivity of carbon. Carbon fiber-glass fiber reinforced plastic composites are, for example, materials for detecting the damage of concrete structures and foretelling the fracture of them [1]. We think that it is possible to apply this technology to grasp the damage of steel structures, then we try to develop the health monitoring system of steel structures by strain sensor functioned with carbon particle-polymer composites.

In this research, the results of fundamental tests on the strain sensor functioned with carbon particle-polymer composites are described.

2. STRAIN SENSOR

The strain sensor is produced on a base film by printing ink which is made by dispersing electric conductive particles into a polymer solution or polymer solutions. Electric conductive paths are formed between the electrodes by chains of particles contacting with each other. The elongation of the sensor caused by an external force results in a change in gap distances between the particles. This results in the change in the electric resistance of the sensor.

We try to grasp the strain distribution of steel structure and estimate the damage of it by measuring the change in the electric resistance of the sensor. It is stuck on the surface of steel structure such as wire strain gages. However, it is characterized by to be larger than the conventional wire strain gage and to be able to measure at a wide extent by one sensor.

The strain sensor used in this research is produced on a PET film (0.12mm in thickness) by printing ink. The ink is made by dispersing carbon graphite particles (35wt%) into a copolymer solution of ethylene-vinyl acetate (ethylene 20wt%) using tetraline as a solvent. The thickness of the print layer is 0.09mm.

3. TENSION TEST OF STRAIN SENSOR

In the first place, the characteristic of the strain sensor itself was examined by tension test of dumbbell shape test piece . The central part of test piece was 25mm long and 10mm wide. Fig.1 shows relation between logarithm of electric resistance and elongation. Though some deviation is recognizable at

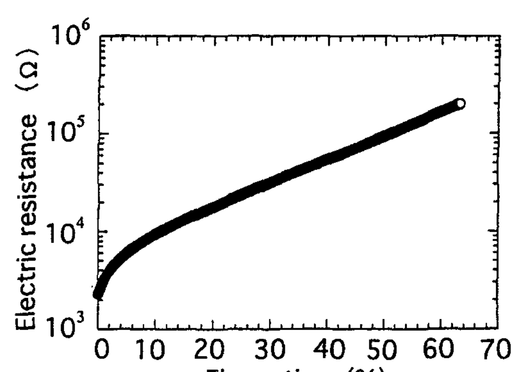

Fig.1 Relation between electric resistance and elongation

first, the linear relation holds between logarithm of electric resistance and elongation. When resistance is plotted in a linear scale, it is found that resistance increases exponentially to elongation. The same test result of hot-pressed test piece is described in Reference [2].

4. TENSION TEST ON STEEL PLATE WITH STRAIN SENSOR

In the second place, the characteristic of the strain sensors, which were stuck on steel plates (25mm wide and 4.5mm thick), was examined by cyclic tension test. Four test pieces were prepared, wherein the strain sensors were 400mm long and 10mm wide and had about 20k Ω in initial electric resistance. Besides, the strain of test piece was measured by a wire strain gage at the center of steel plates.

An example of relation between load and electric resistance is shown in Fig.2. The relation shown in Fig.2 is similar to that between load and strain in steel. At the yield point of steel plate, resistance increases about 3.5% to initial resistance, and at the strain hardening point, resistance increases over 50% to initial resistance. An example of relation between electric resistance and strain is shown in Fig.3. The steep increase of resistance at about 2000 μ of strain and from 15000 μ to 20000 μ of strain means the yielding of steel plate distance from the wire strain gage. The slight increase of resistance from 2000 μ to 15000 μ of strain means the yielding of steel plate nearby the wire strain gage.

Relation between recorded maximum strain and remained electric resistance is shown in Fig.4. Though some deviation is recognizable, it is found that we can presume the recorded maximum strain from the remained electric resistance.

5. ALTERNATE BENDING TEST ON H SHAPE STEEL WITH STRAIN SENSORS

Furthermore, the characteristic of the strain sensors, which were stuck on H shape steel (H-150× 150 × 7 × 10), was examined by alternate cyclic bending test. 11 pieces of strain sensors (35mm in length, 22mm in width and about 45 k Ω in initial electric resistance) were stuck on upper and lower flange respectively. Besides, the strain of H shape steel was measured by wire strain gages (WSGs). Fig.5 shows the test setup. Tested H shape steel was simply supported at a total span of 900mm and loaded at a concentrated loading point.

Relation between load and electric resistance (center of span at upper flange) is shown in Fig.6. As the resistance do not become negative, the relation

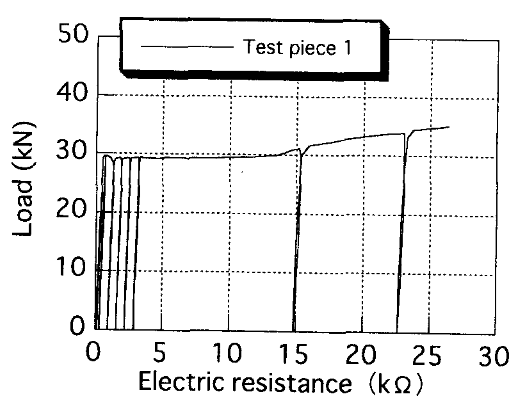

Fig.2 Relation between load and electric resistance

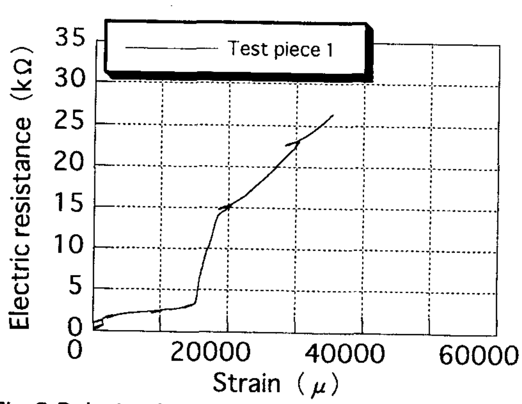

Fig.3 Relation between electric resistance and strain

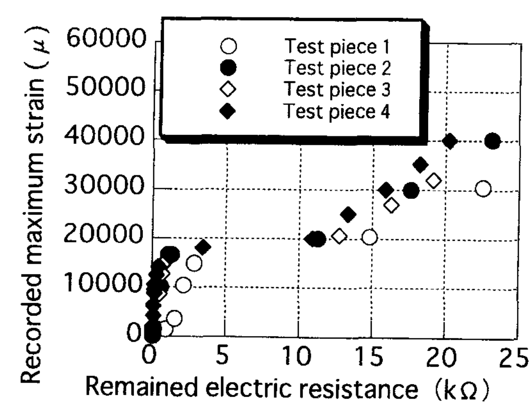

Fig.4 Relation between recorded maximum strain and remained electric resistance

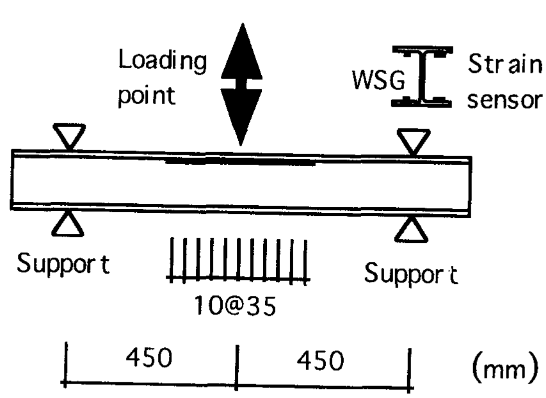

Fig.5 Test setup

shown in Fig.6 differs from that between load and strain in steel. Relation between electric resistance and strain (center of span at upper flange) is shown in Fig.7. It is confirmed that the resistance has a tendency to increase even at compressive stages. We suspect that the chains of particles are disconnected by compressive force.

Relation between recorded maximum strain and remained electric resistance is shown in Fig.8. The detail of it at the first loading stage is shown in Fig.9 as well. At the first loading stage, the data varies in the case of compressive strain. Furthermore, it turns

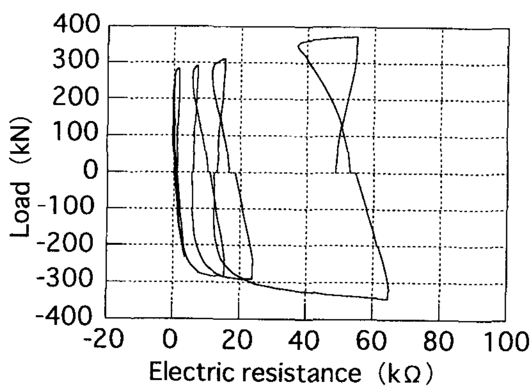

Fig.6 Relationship between load and electric resistance

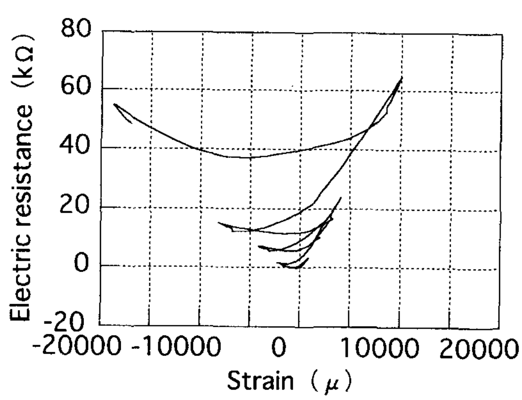

Fig.7 Relation between electric resistance and strain

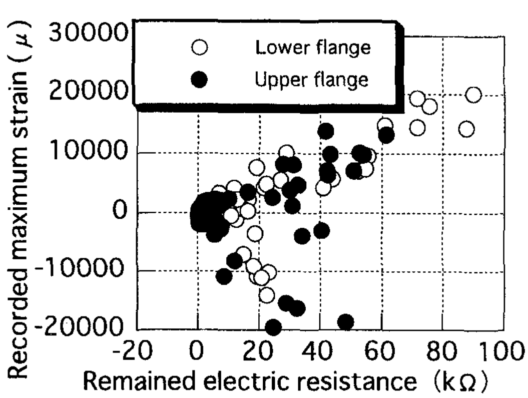

Fig.8 Relation between recorded maximum strain and remained electric resistance

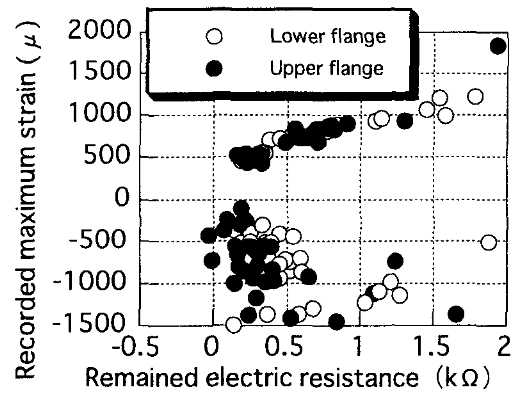

Fig.9 Relation between recorded maximum strain and remained electric resistance

out that the remained electric resistance depending on compressive strain is different from that depending on tensile strain. We recognize that it is difficult at the present condition to presuming exactly the recorded maximum strain from the remained electric resistance of the strain sensor which is stuck on steel structure subjected to alternate loading.

6. CONCLUSIONS

Fundamental tests on the strain sensor functioned with carbon particle-polymer composites were put into operation. The following conclusions were obtained.

(1) A linear relation holds between logarithm of electric resistance and elongation in the strain sensor itself.

(2) We can presume the recorded maximum strain from the remained electric resistance in the case of tension steel members.

(3) The remained electric resistance depending on compressive strain is different from that depending on tensile strain in the case of steel structure subjected to alternate loading.

(4) The problem to resolve remains about presuming the recorded maximum strain from the remained electric resistance of the strain sensor.

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