Developing a Piezoresistive Structural Sensor to Monitor the Pressure and Strain on the Walls of a PVC Water Pipe

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Abstract: The pressure and strain acting on the walls of a water pipe was monitored using a polymer based piezoresistive structural sensor (PRSS) and commercially available strain gage. Rectangular shaped PRSS was developed for this application to sense small pressures and strains. The average gage factors of the PRSS were determined as 33.9 and 28.3 in the circumferential and axial directions respectively. The PRSS exhibited very high sensitivity and it was around 15 times more sensitive than the strain gage.

1. Introduction

In order to increase the reliability of a structure, it is important to monitor the performance under service conditions. This kind of inspection needs sensors to be attached at the critical places of the structure. However, common sensors have some deficiencies which are difficult to overcome like they cannot be attached to the structural material at the critical places, embedding the sensors will alter the integrity of the structural material, some of them require trained personnel to execute rendering them as tedious and expensive and most of them have shorter working life (Hou and Lynch, 2008). Hence, there is need to develop sensors to be used for monitoring during the service life of the structures.

2. Objectives

The overall objective of this study is to develop a PRSS to monitor the pressure acting on the wall of a PVC water pipe and comparing its sensitivity with the strain gage

3. Materials and Methods

In preparing the PRSS specimens, polyester resin was used as the binder. Thick paper molds were used to cast the specimens. Rectangular specimens (1.5 × 0.8 × 0.3 in.) were cast on the pipe to be tested and were allowed to cure at room temperature (about 25^0 C) for 24 hours. Wires, used for the resistance measurement, were embedded during the preparation of the specimen.

4. Experimental Study

PRSS specimens were placed close to the strain gages (Omega Engineering, USA, Resistance = 120 Ω, Gage factor = 2.08) on similar orientations. Pipe testing arrangement is shown in Figure 1(a). During the test, pipe was filled with water and pressurized using compressed air. Strains were measured using the strain gage readout and the resistance values of PRSS were measured using the multimeters.

5. Analysis

When a cylindrical pipe is subjected to stresses in the axial (σ_a) and circumferential (σ_θ) directions at once, stress and strain on the axial (ϵ_a) and circumferential (hoop) (ϵ_θ) directions can be represented as follows

$$\epsilon_\theta = \frac{\sigma_\theta}{E} - \nu \frac{\sigma_a}{E} \quad \text{……………….. (1)}$$

$$\epsilon_a = \frac{\sigma_a}{E} - \nu \frac{\sigma_\theta}{E} \quad \text{………………...(2)}$$

The gauge factor (M_i) is defind as $[\Delta\rho/\rho_0]_i = M_i \Delta\epsilon_i$ ………………...(3)

where $\Delta\rho/\rho_0$ is the change in specific electrical resistivity, E is the modulus, ν is the Poisson's ratio and $\Delta\epsilon$ is the change in strain. In this study gage factor is used to compare the sensitivities of the PRSS and the strain guage.

4. Results and Discussions

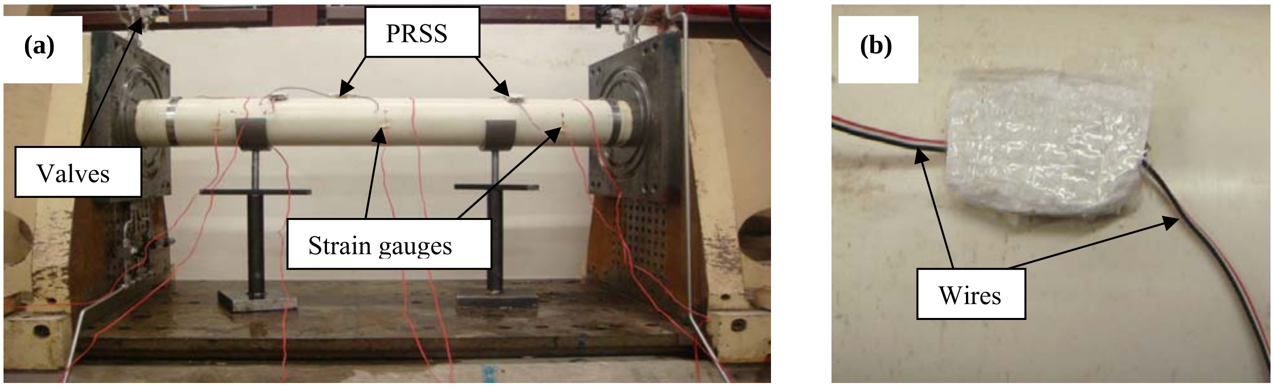

Figure 1.(a) Pipe testing arrangement (b) PRSS cast on the pipe

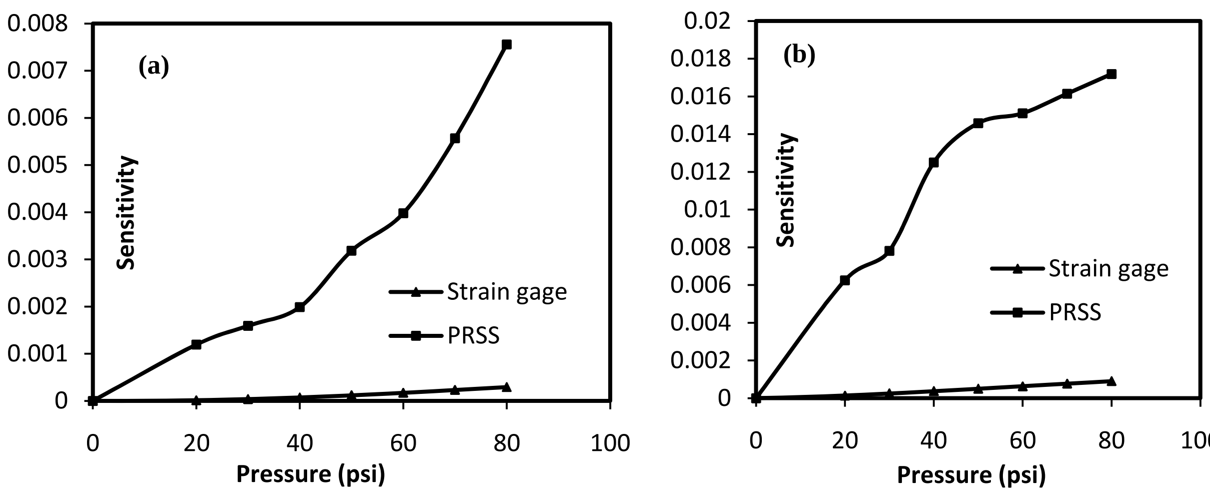

Figure 2. Comparison of the sensitivities in the (a) circumferential and (b) axial directions

From Figures 2 (a) and (b), the average gage factors of the PRSS were determined as 33.9 and 28.3 in the circumferential and axial directions respectively.

5. Conclusions

PRSS exhibited very high sensitivity compared with the strain gages in both axial and circumferential directions and it was around 15 times more sensitive than the strain gage. Therefore, PRSS can be used as a sensor to monitor the water pressure and the strain on the PVC pipe walls.

6. Acknowledgement

This study was supported by CIGMAT with partial funding from the City of Houston and US Airforce. Sponsors are not responsible for any of the findings.

7. References

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