Dynamic Stress Reduction System

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Abstract

By utilizing a piezoelectric device as the actuator system in a feedback control loop we demonstrate a reduction of stress concentration on a cantilever beam with a *k* value of 1.24. The stress reduced was shown to be in the order of 24 MPa for an aluminum beam using strain measuring techniques. The piezoelectric actuator and its capability to reduce stress concentration, provided evidence to support its potential use as an actuator system to regulate stress in a dynamically loaded member. Finite Element Analysis models were used to predict the response of the beam to the inverse piezoelectric effect from the actuator. These models showed promising results in predicting the effects of piezoelectric actuation on structural members. We compared the performance of various types of controllers such as a proportional integral derivative (PID) and a proportional integral (PI).

Introduction

In their simplest form, smart materials are designed to undergo property changes in a controllable manner due to changes in their environment. There are a wide range of smart materials, each of which offer unique properties. This new breed of materials has drawn increasing interest due to their potential role in material science. Through the development of a dynamic loading system and a series of strain measurement experiments we strive to determine the feasibility of piezoelectric devices as system actuators in a feedback control loop for reducing stress.

Theory

Due to the inverse piezoelectric effect, piezoelectric material is capable of producing a stress within the sample. Therefore, suitable structures made of these materials can be designed to bend, expand or contract when a voltage difference is applied.

Consequently, utilizing a piezoelectric actuator to produce a bending moment in order to oppose an external load on a member could potentially lead to a reduction in the stress experienced by the member. However in order to reduce stress, the piezoelectric device must posses the capability of producing a large amount of force.

Fig 1. Piezoelectric actuator bonded to an Aluminum beam.

Methods

In order to perform a dynamic stress test, we began by developing a cantilever loading system (Fig. 2) utilizing a stepper motor. The specifications of the loading system were determined from the dimensions of the aluminum test sample. The cantilever beam was chosen to be 10"x1.5"x.125". Finally, the piezoelectric actuator was bonded to the bottom face of the aluminum beam centered on notch for convenience and ease of use.
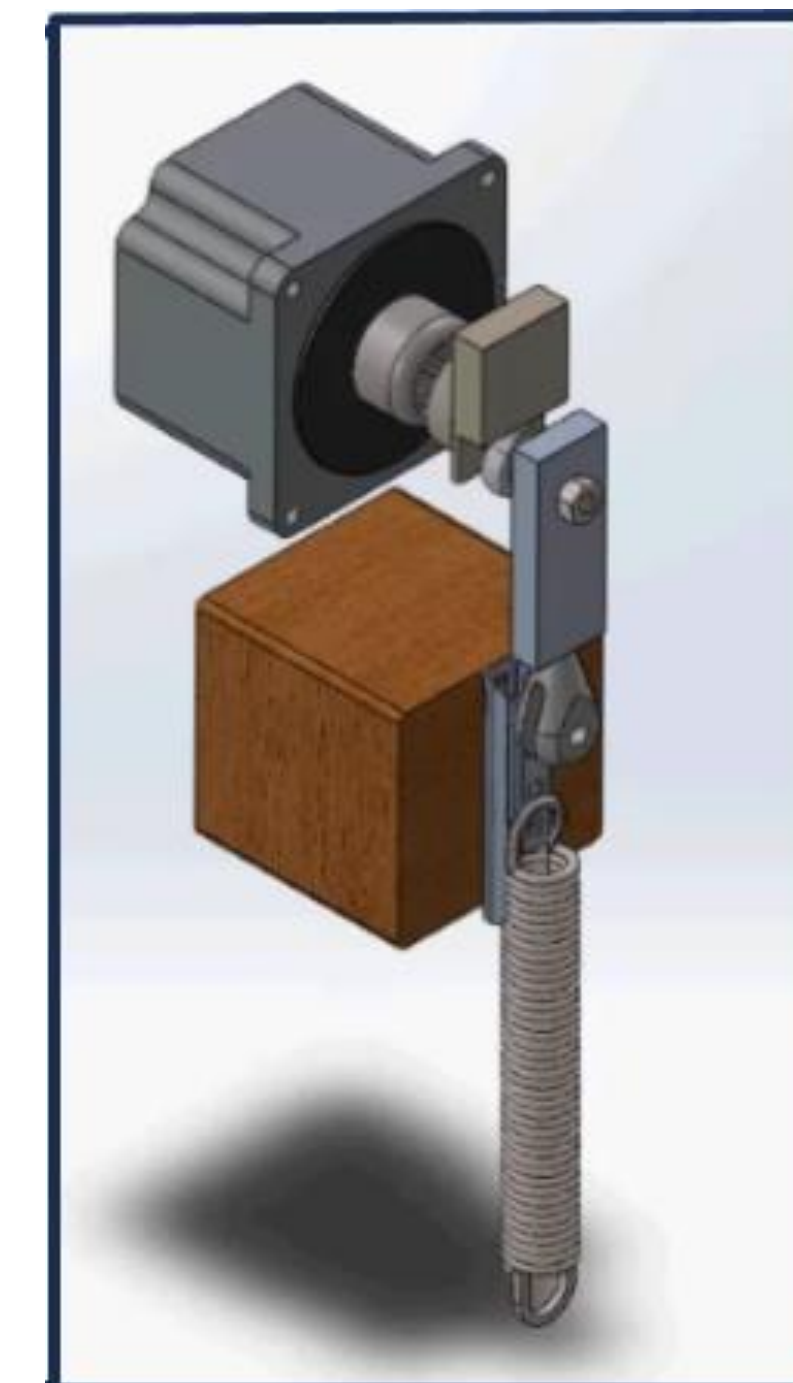

Fig 2. Loading system.

Results

The strain experienced by the cantilever aluminum beam is presented in figure 3. The plot on the left is the strain experienced by the beam when the control system was disabled. Once enabled the control system showed promising results by reducing the amount of strain equivalent to approximately 3N of force.
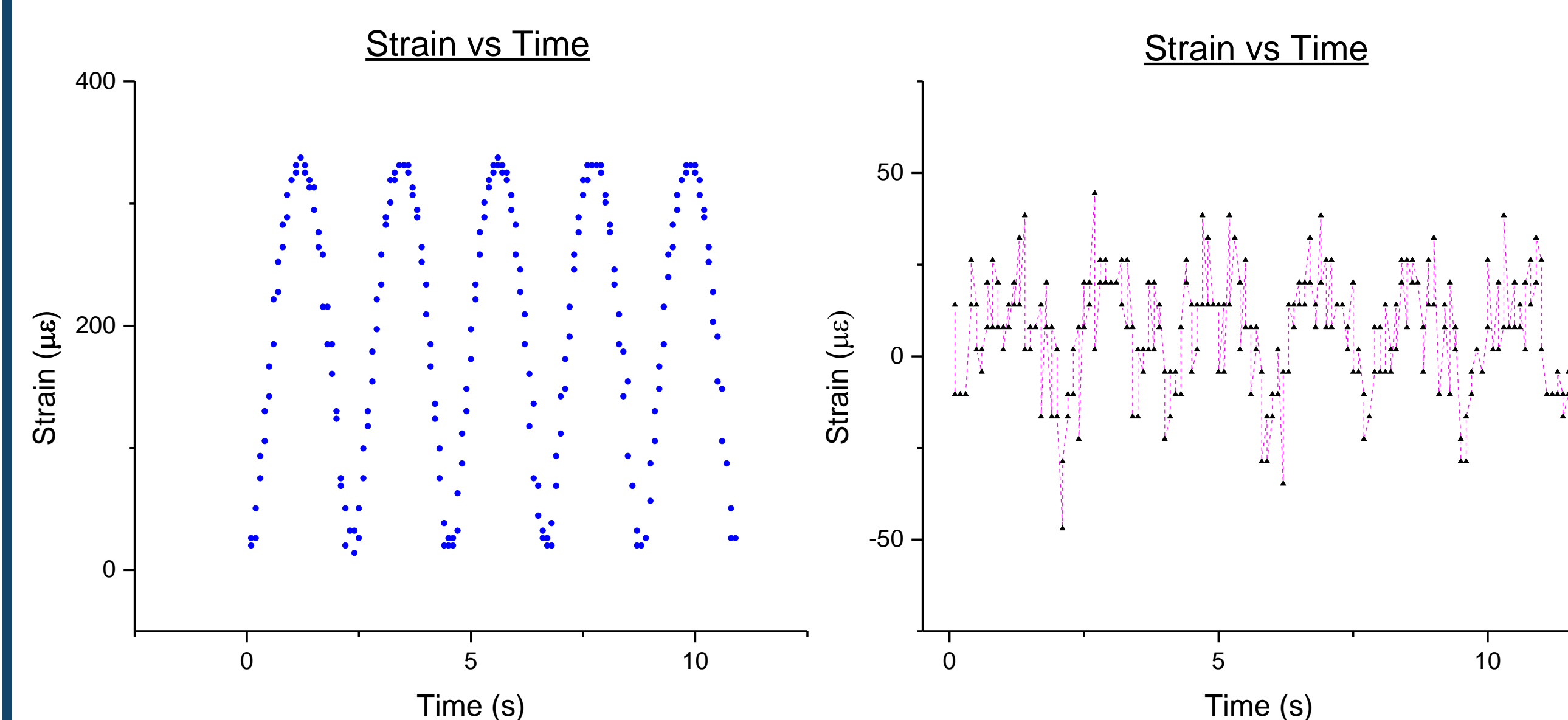

Fig 3. No controller (Left) strain measurements. PI controller (Right) strain measurements.

Discussion

Although the piezoelectric actuator was specified to have a 775 N blocking force, the strain reduced was determined to be in the order of 3N with a static loading test. The relatively low force reduction was primarily due to the orientation of the piezoelectric actuator and the geometry of the material chosen. Results for different controller algorithms were compared. It was determined that the PID and PI controllers performed best during the low frequency testing (Table 1). Due to time constraints further testing with random loading could not be performed and evaluated.

Table 1. Controller algorithm strain comparison

No Controller	P	PD	PI	PID
$0 - 350\ \mu\varepsilon$	$-100 - 100\ \mu\varepsilon$	$-60 - 60\ \mu\varepsilon$	$-40 - 40\ \mu\varepsilon$	$-40 - 40\ \mu\varepsilon$

Conclusion

We demonstrated that piezoelectric actuators are capable of reducing stress concentration from a dynamically loaded member. Although our experiment was limited to low frequency loads, we are confident that our results can be used as evidence to support, with the correct equipment, that piezoelectric actuators can be used to relieve unpredictable stress experienced by structural members.

Acknowledgements