# Measuring Strain in Running Shoes Under a Typical Running Condition

**Author:** Matthew Lilyquist, Student

A strain gage from Micro-Measurements was used to measure the amount of strain present in the sole of a running shoe when exposed to forces typical of jogging on a treadmill. The particular strain gage was chosen due to its compatibility with the amount of flexure expected from the shoe during the process of running and its ease of installation.

**Company/Institute:** University of Minnesota

**Industry/Application Area:** Mechanical Engineering Laboratory

**Product Used:**

- C2A-13-250LW-350 strain gage, configured in a quarter bridge
- M-Prep surface preparation
- M-Bond 200 gage adhesive
- M-Coat A polyurethane coating

## The Challenge

For an independent project for Basic Engineering Measurements Laboratory class, the student wanted to measure the amount of resultant strain in the sole of a running shoe while exposing it to typical forces during jogging. This required selecting a compact strain gage that is designed for moderate to high elongation, and an adhesive that could bond to the polyurethane sole of the shoe. See Appendix for theoretical strain requirements.

## The Solution

After speaking with an engineer at Micro-Measurements, the student decided on the C2A-13-250LW-350 strain gage, which would be adhered to the shoe sole in a recess between treads, using the M-Bond 200 adhesive. The C2A gage, which has pre-attached leads, was chosen to avoid potential damage caused by soldering. Coupled with a compact data acquisition device and a laptop computer, this device could be used to adequately measure the amount of axial strain present.

**The User Explains**

Typical strain gages can measure very small amounts of elongation, often on the order of $10^{-6}$ of strain (or 1 µe). Due to the elasticity of the shoe sole, this application would produce elongations on the order of 10-2 strain (or 10,000 µe). This elongation is well within the strain measuring capability of the C2A gage, as it is able to measure up to 3% strain or 30,000 µe.

The student adhered the strain gage to the shoe sole, shown below in Figure 1, and then connected the strain gage circuit to the data acquisition device and the laptop, which ran a simple strain calculating LabVIEW program.

"It was very important for the student to acquire a good set of baseline readings from the strain gage prior to taking data during jogging, advised Donielle Dockery, a Micro-Measurements senior field design engineer.

A zero reading was taken with the shoe off and at rest, with no loading. That was followed by a static reading with the shoe on the foot of the student while standing still. Next, the student ran on a treadmill at a steady pace and cadence, and the strain data was sampled.

*Figure 1: Strain gage mounted to shoe sole*

Although there were sources of uncertainty that were not accounted for, such as inconsistencies in the runner's form, temperature changes, and very slight peeling of the M-Coat A protecting coating and adhesive due to the large amount of flexure of the sole, the C2A gage produced good results.

“The measurements taken during the baseline evaluation of the installed strain gage under static load showed an initial dead weight strain level of about 0.004 strain or 4000 µe which can be easy be seen throughout the jogging process while peak strains at impact were nominally 0.014 strain or 14,000 µe,” noted Dockery. Figure 2 below represents graphical data strain levels while jogging.

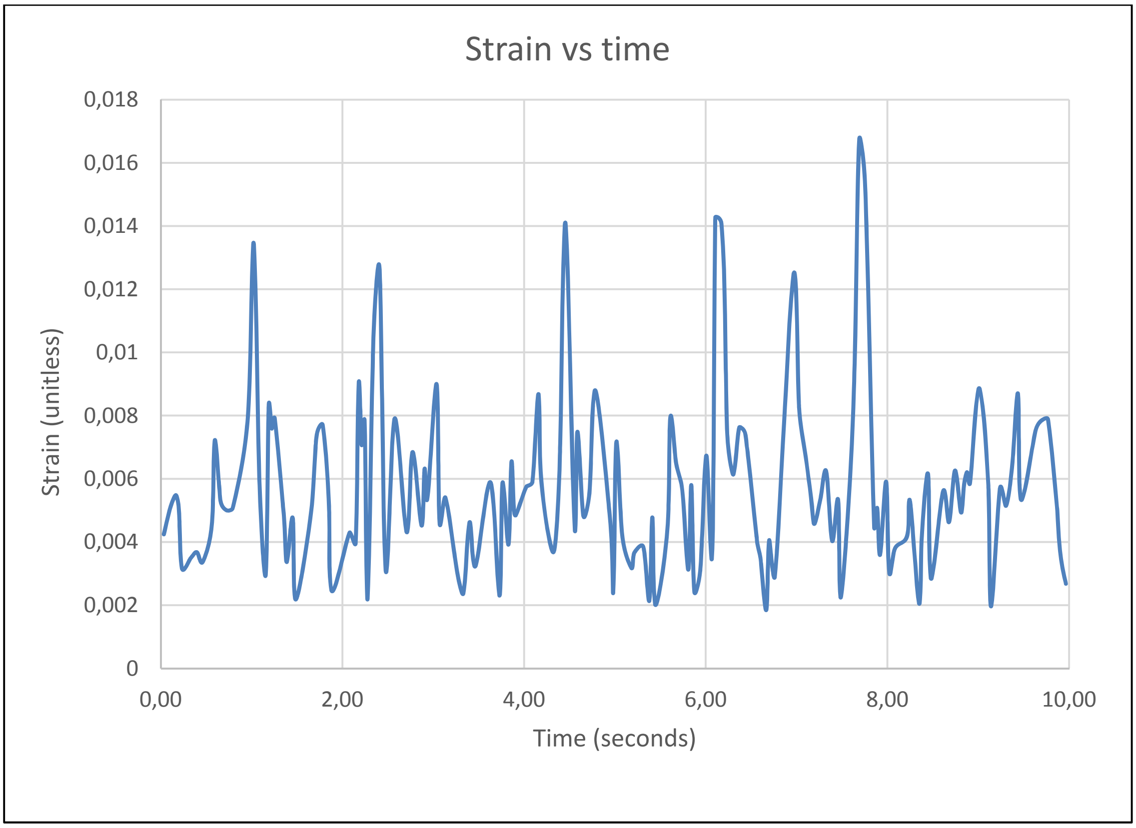


*Figure 2: Strain as a function of time*

**Revisit: Shoe Strain Level**

“Although M-Bond 200 was used in the jogging profile above, the adhesive system and C2A gage selection did not allow for the maximum strain capability of the shoe in more stress-based exercise efforts,” according to Dockery. “For greater strain detection, I would choose a different adhesive such as AE-15 and an alternate gage such as an EA or EP series gage as this would be a better selection for improving on the peak strains produced by the shoe”, stated John Hill, Sales Engineer from Instrumentation Resources.

## Appendix: Theoretical Strain Calculations

Initial over-simplified calculations for the required strain gage tolerance were made by modeling the shoe as a simply loaded beam. To do so, the shoe sole was assumed to have a uniform cross-sectional area, and dynamic forces were ignored. However, the student used conservative estimates for dimensions and the modulus of elasticity. Figure 3 shows this simplified model.

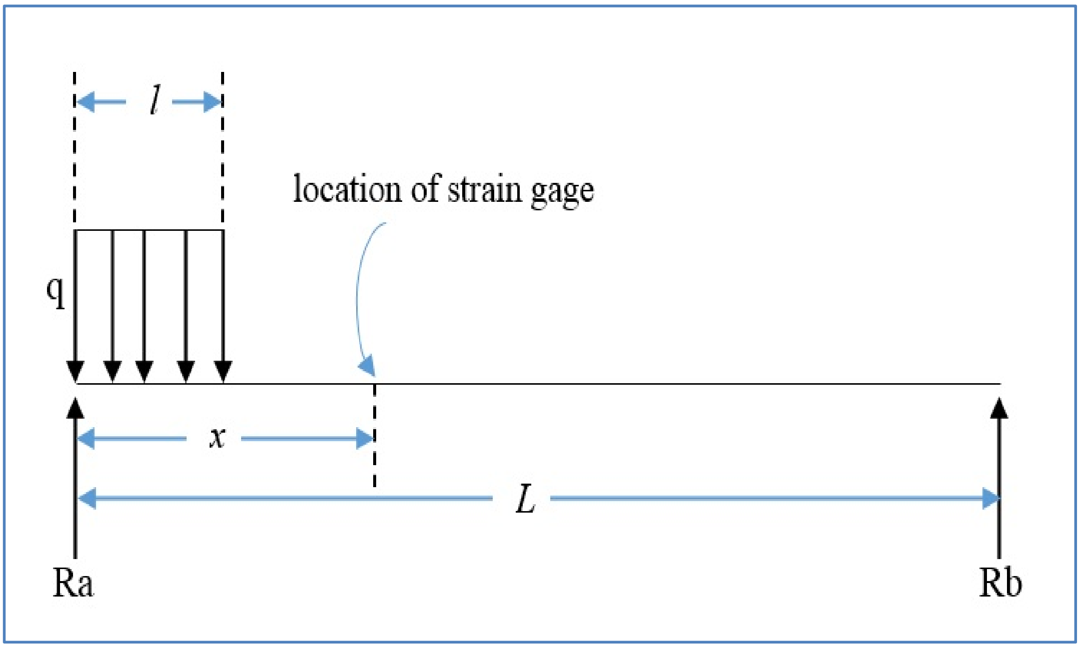


*Figure 3: Shoe modeled as simply loaded beam, where L is the length of the shoe sole, l is the diameter of the runner's ankle, q is the runner's weight divided by the ankle diameter, and x is the axial distance from the heel of the shoe to the location of the strain gage. This model was used to calculate a required strain of 1.4% (14,000 με).*

***"The use of C2A gages from Micro-Measurements eliminated the need for soldering on wires, thus shortening my overall testing time."***

**Acknowledgement**

I would like to thank John Hill from Instrumentation Resources and Donielle Dockery from Micro-Measurements for their immeasurable guidance and support in this project.

## Contact Information

Matt Lilyquist,
University of Minnesota
College of Science and Engineering
Student at University of Minnesota
117 Pleasant St SE
Minneapolis, MN 55455
Email: neuha034@umn.edu

Vishay Precision Group, Inc. (VPG)
Micro-Measurements
Email: mm.us@vpgsensors.com

Instrumentation Resources
17808 Excelsior Boulevard,
Minnetonka, MN 55345 USA
Phone: (952) 797-0220
Cell: (763) 350-8693
Email: tony@irisensors.com
Web: www.irisensors.com