VIRTUAL INSTRUMENTATION FOR MEASUREMENT OF STRAIN USING THIN FILM STRAIN GAUGE SENSORS

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ABSTRACT:

This paper describes the development of thin film strain gauge sensor for strain measurement and indication using LabVIEW. The strain gauges designed were deposited on either side of the cantilever of Beryllium copper (Be-Cu) using DC magnetron sputtering technique. LabVIEW version7.1, signal conditioning connector block SCC2345 with half bridge type II strain gauge input module SG03 and Data Acquisition (DAQ) board 6221 have been utilized for the acquisition and indication of strain. Strain was also calculated & compared with the indicated value. The error found to within 0.5%. The developed strain gauges are expected to be used in aerospace and biomedical applications for the measurement of micro strain.

Keywords: strain, Thin film strain gauge, LabVIEW.

INTRODUCTION

Measurement of strain is important in automotive and biomedical applications, aerospace industries, and also in seismic testing of bridges and other structures [1]. Strain depends on the amount of deformation of a body due to an applied force. More specifically, strain is defined as the fractional change in length. While there are several
methods of measuring strain, the most common is with a strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device.

Strain gauge is a sensing device or sensor used to measure the linear deformation occurring in the material during loading [2]. Based on the principles of operation, strain gauges are classified as electrical, mechanical, optical, acoustical and pneumatic [3]. Among these the electrical strain gauges have become widely accepted and at present dominate this field. The different types of electrical strain gauges are metallic foil, semiconductor and thin film. Foil type strain gauge sensor is the most commonly used one, but it has limitations such as thermal degradation, relatively low output signals, requirement of careful installation procedures and degradation in performance due to moisture effect [4]. These limitations are overcome by using thin film sensors. Hence thin film strain gauges have widespread use in industry. Different kinds of materials that are used for thin film strain gauges are metals, alloys, cermets and semiconductors. The high resistivity of alloys along with their low temperature coefficient of resistance (TCR) and good temporal stability make them prime candidates for strain gauge application. Nichrome (NiCr 80/20 wt.%) is the most widely used alloy because of its high resistivity, low TCR, commercial availability, low temperature dependence of gauge factor and similar properties[5].

The aim of this work is to design and develop Nickel-Chromium (NiCr) thin film strain gauge sensors and interface with associated instrumentation for strain measurement and indication using Virtual Instrumentation

A virtual instrumentation system is the use of customizable software and modular measurement hardware to create user defined measurement systems.

National Instruments (NI) LabVIEW data acquisition hardware and software modules have become one of the most widely used tools to capture, view, process and control. Hence, NI hardware has been utilized in our work also.

2. DEVELOPMENT OF THIN FILM STRAIN GAUGES

The strain gauge development involves the design of strain gauge, preparation of cantilever beam (substrate), deposition of thin film strain gauges on it and wiring. The suitable pattern required for the thin film strain gauge was designed using AutoCAD. A
photo plot of designed gauge pattern was obtained and, with the help of it, mechanical masks of Be-Cu material were made.

The surface condition of the substrate and the type of the substrate material used influence the performance of thin films [6]. The surface roughness of the substrate affects the adhesive property of thin films [7,8]. Hence prior to the application of the polymer layer, the surface of the substrate was prepared using standard polishing and cleaning procedures. In the present work Beryllium-copper (Be-Cu) material (98% copper and 2% Beryllium) has been chosen as substrate, because Be-Cu is a highly ductile material, which can be stamped and formed into very complex shapes with the closest tolerances. Be-Cu can be strengthened by precipitate hardening. Heat treated Be-Cu features excellent dimensional stability, fatigue resistance and corrosion resistance and mechanical strength.

In order to electrically isolate the thin film strain gauges from the metallic surface, a thin layer of an epoxy adhesive (M-Bond 610) was applied on either side of the substrate. This polymer provides the highest level of performance and is suitable for temperatures up to +230°C. The polymer layer was applied uniformly on the required region and heat treatment of the substrate was done immediately in a temperature-controlled oven at 150°C for about 2hrs.

Using the mechanical masks, thin film strain gauges were deposited on either side of the cantilever beam using the DC Magnetron sputtering technique. This technique has been chosen because of its high ionization efficiency and good adhesion of the deposited films & better molecular bonds that will ensure faithful transfer of strain experienced by the strain gauges.

The sputtering system used consists of an arrangement in which a plasma discharge was maintained between the anode or substrate (Be-Cu) and the cathode or target (Nickel-Chromium). The chamber of the system was initially evacuated to a pressure of $10^{-6}$ torr using a combination of rotary and diffusion pump and back filled to sputtering pressure with the inert gas argon [9,10]. The deposition parameters were optimized to achieve the required properties for the film. Thin film strain gauges of Nichrome were sputter deposited on either side of the cantilever.
3. TRANSDUCER PARAMETRIC ANALYSIS

A mechanical setup was designed and developed for study the characteristics of
the strain gauge developed. The setup consists of a rectangular base plate made of brass
material with a cylindrical rod fixed vertically at the left wherein a fixture has been
provided for holding the strain gauges in the form of a cantilever. The free end of the
cantilever can be deflected by means of a digital micrometer fixed to a holder. Fig.1
shows the photograph of the cantilever set up with strain gauges.

![Figure 1 Shows the photograph of the cantilever set up with strain gauges.](image)

The fractional change in resistance with respect to deflection of the cantilever
were stored in the data files. Using National Instruments LabVIEW version 8.0, VI block
diagram was created with spread sheet read icon and express xy plotter as shown in fig2.
Data read by spread sheet reader and plotted in the xy plotter is found to be linear for
both compression & tensile mode and is as shown in figs 3 & 4

![Figure 2 VI Block diagram to read & plot compression & tensile mode resistance values](image)
The gauge factor of the strain gauges developed were determined to be ~ 2.7 using four point bending method.

4. HARDWARE DESCRIPTION

The block diagram of the strain measurement system developed is shown in Fig.5 and the function of each of the blocks is explained below.

![Block diagram of strain measurement system](image)

**4.1 Sensor Unit.**

The sensor unit consists of a cantilever with thin film strain gauges on either side. The cantilever was fixed to the mechanical setup.

**4.2 Signal conditioning unit.**

This unit consists of NI signal conditioning connector block SCC2345 and strain gauge input module SG03 [11]. The SCC2345 has 20 SCC sockets, labeled J1 through J20. Sockets J1 through J8 accommodate SCC modules for conditioning signals on the analog input channels of the DAQ card.

SCC-SG03 is a dual-channel strain gauge module for conditioning half bridge strain gauges. This module has two strain gage input channels, offset nulling circuitry for
each channel and a 2.5V excitation source. Each input channel includes an instrumentation amplifier with differential inputs with a fixed gain of 100. The output of each amplifier is filtered and buffered to prevent settling time delays.

4.3 DAQ unit:

DAQ card PCI6221 is required for the interfacing purpose. Hardware functionality includes 16 analog inputs, 2 analog outputs, 24 digital I/O, counter/timers, triggering and synchronization circuitry.

4.4 Personal Computer with Labview

Personal computer with labVIEW version7.1 has been used for acquisition and indication of strain, in our present work.

5 DATA ACQUISITION AND PRESENTATION USING LABVIEW

The cantilever was fixed to the mechanical setup fabricated and strain gauges were connected to the strain gauge input module SG03. The bridge completion resistors present in SG03 completes Wheatstone bridge configuration. SG03 module was inserted into one of the analog input sockets of the SC2345 connector, which in turn was connected to the PC through DAQ card 6221. The experimental set up is as shown in fig.6

![Figure 6 Photograph of the experimental set up](image)

The data acquisition board was configured for strain measurement using the measurement & Automation Explorer (MAX) of LabVIEW. Configuration was done by entering the gauge factor, gauge resistance, minimum & maximum values of strain to be indicated & setting the excitation voltage as internal. The strain gauge input module SG03 was configured as half bridge type II which measures only bending strain [12].

The block diagram VI & front panel VI were constructed using appropriate icons & function pallets of NI DAQmx on LabVIEW platform. These are shown in Figure 7 & Figure 8 respectively.
Known weights were added in steps to the free end of the cantilever and the corresponding amplified & filtered bridge output voltage of SG03 was acquired by analog input (AI) channel by continuous sampling and was converted to strain, using convert to strain inbuilt functions present in block diagram VI and was stored in the system for indication in the front panel VI. The true value of strain was also calculated using physical dimensions of cantilever. Variations of mass versus indicated & calculated strain are as shown in Figure 9.
6. CONCLUSIONS

Using Labview strain was indicated as micro strain. The LabVIEW measurement platform has dramatically reduced test times as results were automatically collected. This type of Strain measurement system can be used in closed loop for aerospace and biomedical applications.

ACKNOWLEDGEMENTS

The authors thank Siddaganaga Institute of Technology, Tumkur, Karnataka, India, for supporting this research work.

REFERENCES


[12] National Instruments Data Sheet

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