Chapter 6
Measurement of Strain Using Strain Gauge and Piezoelectric Sensors

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ABSTRACT

Today, measurement of strain plays a crucial role in different areas of research such as manufacturing, aerospace, automotive industry, agriculture, and medical. Many researchers have used different types of strain transducers to measure strain in their relevant research fields. Strain can be measured using mainly two methods (i.e., electrical strain sensors and optical strain sensors). Electrical strain sensors consist basically of strain gauges, piezo film, etc. In electrical strain sensors, the strain gauge is one of the oldest and reliable strain sensors which are available in different types (i.e., wire strain gauge, foil strain gauge, and semiconductor strain gauge). Piezofilm is also playing an important role in the field of strain measurement due to easy availability and less cost.

INTRODUCTION

Measurement of strain plays a crucial role in various areas of research, including manufacturing, aerospace, automotive, agriculture, and medical. Many researchers have used strain transducers to measure strain within their relevant fields. Strain can be measured using the electrical strain sensor and optical strain sensor. Electrical strain sensors are the oldest and most reliable sensors. These include the wire strain gauge, foil strain gauge, and semiconductor strain gauge. Piezo film, which also plays a vital role in the field of strain measurement, is readily available and more affordable. Optical strain sensors, which are

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based on fiber Bragg grating (FBG) technology, are often used in monitoring fields like civil engineering structures and wind turbines. This chapter discusses strain measurement sensors and their applications. Most researchers have studied the measurement of strain using the sensors discussed in this paragraph.

Regarding hypersonic force measurement, strain gauges and piezo films are commonly used to detect stress wave propagation in a solid bar. Storkmann et al. (1998) designed a six-component strain gauge force balance for three models: (1) pointed cone; (2) Apollo CM capsule; and (3) delta wing configuration ELAC I. A pointed cone and Apollo CM capsule model were tested in the Aachen shock tunnel TH2. The capsule model was also tested in the von Karman Institute Longshot Wind Tunnel facility.

Robinson, Martinez Schramm, and Hannemann (2011) designed a three-component stress wave force balance using the cone model. The stress wave balance, in coordination with the model, was mounted in the high-enthalpy free-piston shock tunnel for experiments.

Wang, Liu, and Jiang (2016), using a finite element method, designed several pulse-type strain gauge balances for three components to optimize characteristics. Force tests were conducted for a large-scale cone with a 10° semivertex angle and a length of 0.75m in the JF12 long-test-duration shock tunnel. The finite element method was used for the analysis of the vibrational characteristics of the model-balance-sting system (MBSS) to ensure a sufficient number of cycles, particularly for the axial force signal during a shock tunnel run. The higher-stiffness strain gauge balance in the test shows excellent performance. The frequency of the MBSS increases due to the stiff construction of the balance. Based on the similar concept of strain measurement, another strain sensors, polymer piezoelectric film, was employed by various researchers in the field of strain measurement.

Duryea and Martin (1968) developed a six-component piezoelectric force balance (slender configuration only) for measuring aerodynamic forces and moments in high-speed flow at Cornell Aeronautical Laboratory, New York. The balance was designed using H-type, E-type, and K-type piezoelectric sensor (PZT) material. It was compared based on feasibleness and high load capabilities.

Min, Yang, Qiu, Zhong, and Pi (2018) designed a new three-component fiber optic force balance based on the micro-electro-mechanical-systems (MEMS) Fabry-Perot (FP) strain sensor and test in a low-density hypersonic wind tunnel. The researchers aimed to achieve a faster response, higher sensitivity, and antielectromagnetic interference as compared to conventional strain gauge balance. It was observed that the fiber optic balance calibration and wind tunnel test had good agreement with the results of traditional strain gauge balance. In addition, the MEMS FP strain sensor was suitable for the application of hypersonic force measurement.

**STRAIN**

When objects like metallic bars, columns, or beams are subjected to external forces, an internal resistance is generated inside that object. This, in turn, resists external forces. This internal resistance is termed “stress.” The dimensions of the object (i.e., length, width) change due to this stress. The ratio of change in dimensions to original dimensions is termed “strain.” For example, if a metallic bar with length “L” and Diameter “D” is subjected to an external force, the amount of change in length is “dL.” Therefore, the strain produced in the metallic bar is defined as:

Strain (\( \varepsilon \)) = change in length/original length
= \( \frac{dL}{L} \)
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