Chapter 3
An Overview of Stress and Strain Measurement Techniques

Anil Kumar Rout  
*Indian Institute of Technology, Guwahati, India*

Niranjan Sahoo  
*Indian Institute of Technology, Guwahati, India*

Vinayak Kulkarni  
*Indian Institute of Technology, Guwahati, India*

ABSTRACT

Stress and strain are mechanical behaviour of materials, subjected to mechanical or thermal loading. The detrimental effect of such loading is the ultimate failure of materials due to generation of high stress and strain. Therefore, measurement and prediction of stress and strain values help in proper design and maintenance of engineering equipment and structures. The present contents elaborate and summarize different methods adopted by researchers for mechanical stress and strain measurements. The content is focused to provide an overview regarding the measurement techniques adopted for strain measurement. The analysis holds information regarding working principle of different strain measuring technique along with a brief description about the history of strain measurement. Special attention has also been devoted for explanation of thermal stress and strain measurement techniques. The modern non-contact techniques have evolved as a potential tool for such measurements even at higher temperature conditions.

INTRODUCTION

Stress is the quantification of internal forces that neighboring particles exert on each other in a continuous material. Figure 1 shows the tensile loading on a bar. By definition, stress(σ) is defined as the intensity of force at a point, i.e.,

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(1) \[ \sigma = \frac{dF}{dA} \text{ with } dA \to 0 \]

According to the nature of external loading, the force may be compressive or tensile. The normal component of the force (perpendicular to the cross-section area) is the normal force, and the tangential component of the force is called tangential force. The corresponding stresses are called tensile/compressive stress and shear stress, respectively. However, in real life, combined stresses are seen to be applied many times. Stresses are also generated through thermal effects.

Most of the existing materials in nature expand when subjected to a rise in temperature and contract when cooled. Figure 2 shows the thermal stress induction subjected to no constraint, and Figure 3 shows the thermal stress induction subjected to constraints with rigidly fixed ends. This expansion and contraction bear a proportionality relationship with the change in temperature for a wide range of temperature values. That proportionality constant is expressed in terms of coefficient of linear thermal expansion (alpha) defined as the change in length a bar of unit length experienced when its temperature is changed by 1º. When a homogeneous body is subjected to a non-uniform rise in temperature, different elements of the body tend to expand by different amounts depending upon their local rise in temperature. In a case of restricted free movement, for the body to remain continuous, each element has to expand in a similar manner, which is against the proportionality increment of length as per local temperature. Therefore, the elements of the body exert upon each other a restraining action resulting in continuous unique elongation at every point. For continuity of displacement, the system of strains produced by this

Figure 1. Stresses in bar

Figure 2. External constraints: No constraint, No thermal stress

Figure 3 External constraints (Thermal stress-induced with a change in temperature)
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