Chapter 36
The Use of a Robotic Arm for Displacement Measurements in a Cantilever Beam

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ABSTRACT

This paper is aimed to present a displacement measurements technique which was performed automatically in a cantilever beam using a robotic arm manipulator. This technique is based on the difference of measured coordinates of the robotic arm manipulator in order to provide displacement results. The robotic arm was supported by a micro-switch sensor which in contact with a sample, measured 21x3 points distributed along the sample. Measurements were performed before and after adding the loads on the free end of the cantilever beam, manufactured in ASTM A36 steel. Experiments were performed through loads of 1.96 N, 4.9 N, 9.8 N and 19.6 N using the robotic manipulator controller. Ten sets of measurement were performed for each load. The average and standard deviation for each set of points were also performed. Results were compared to Finite Element Method (FEM) simulations in order to verify the accuracy of the proposed compared to FEM results. Sum of squared errors presented values lower than 3% demonstrating the potentiality of the proposed technique for industries application.

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1. INTRODUCTION

With the increasing of industrial processes, it was necessary to develop accurate measurement techniques allowing deformation control of materials subjected to loads. Some methods have been developed for measuring industrial products such as coordinate measuring machine (Tasic & Acko, 2011; Gestel et al., 2011; Dhanish & Mathew, 2006). Other methods have been developed in order to determine material properties using measurement techniques (Magalhaes, Braga & Barbosa, 2015; Martınez-Celorio et al., 2010). More specifically, some techniques use resonant frequencies to determine material elastic modulus by vibration analysis and average standard time speckle-electronic interferometry (Kima et al., 2007; Akhter et al., 2009). The use of optical methods (Schwenkea et al., 2002) to determine the elastic modulus from digital image correlation (Brynk et al., 2012) is also applied. On the other hand, robotic arms are used to assist measurement techniques (Kawamura et al., 2013) and deformation can be monitored by robotic hand manipulator (Cretu et al., 2012). Other robotic applications have been developed in different areas (Liu et al., 2008; Tabile et al., 2011; Slamani et al., 2015). However, the use of robotics for measuring deformation is still incipient.

This paper is focused on the use of a robotic manipulator for displacements measurement in specific points of a cantilever beam by applying different loads on its free end. A robotic manipulator recorded pre-defined beam coordinates from different points before and after the load application. The robotic controller calculated the coordinate differences between each corresponding point. This represented the experimental displacements which were compared with those obtained by Finite Element Method (FEM).

FEM is a consolidated simulation method mainly used for stress, strain and displacements analysis (Han et al., 2010; Celik et al., 2011; Sabik and Kreja, 2013; Sánchez et al., 2014; Cardelli et al., 2013). This method is based on the assumption that any geometry is composed by discretized elements of a body in small areas or volumes (Zienkiewicz, 1970). Each element has a specific number of nodes and displacements are calculated after loads application. FEM normally has good agreement with experimental data in engineering and other applications (Magalhaes et al., 2012; He et al., 2010; Petracconi et al., 2010; Wang and Zhang, 2010; Sofias et al. 2014; Cavaliere et al., 2015).

The paper is organized as follows. Section 2 presents the theory and calculation for a cantilever beam. Section 3 describes the materials and methods applied for the experimentation. Section 4 presents the achieved results and discussions. Finally, the conclusions were presented in Section 5.

2. THEORY/CALCULATION

A bar with constant cross section clamped at one end and an extremity in balance is called cantilever beam (Timoshenko and Goodier, 1970) which is illustrated by Figure 1.

When a cantilever beam is subjected by a static load on the free end, the load tends to cause deflection along the beam. The bending moment (M) equations are represented by:

$$M(x) = -Px \tag{1}$$

$$M(x) = EI(d^2v) / (dx^2) \tag{2}$$