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Six d.o.f. displacement measuring device based on a modified Stewart platform

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ABSTRACT

Acquisition of the displacements and deformations of a loaded component is generally a not easy operation. This is especially the case as the component often presents a complex geometry and the deformations involve more degrees of freedom or a combination of them.

Measurement devices used for this kind of application often allow to obtain simplified measurements.

This paper presents a novel measurement device, consisting of six displacement sensors mounted as a parallel mechanism, capable to measure the global deformation of a component in terms of translations and rotations. The deformations are obtained by applying the direct kinematic equations to convert the six displacements read from the six sensors into the three translations and rotations representing the deformation of the component.

The geometry of the device leads to write simplified equations for the direct kinematic that can be solved with a semi-numerical procedure implemented in a program written in Matlab environment.

The results given by this procedure have been validated with the positions obtained from a 3D CAD model of the device, showing perfect agreement between the results.

A prototype has been made and tested on a workbench.

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1. Introduction

In many engineering fields such as the study of the fatigue behaviour of a component it is fundamental to know the global deformation of the object [1]. The deformation could be due in general to a combination of displacements in more than one degree of freedom.

Generally it is not easy to acquire this information because the component has to be equipped with numerous transducers to measure all the deformations and afterwards it is necessary to relate the data, obtained from the transducers, to the actual displacements of the component (three translations and three rotations). This measurement can be done by arranging the transducers as in a parallel structure.

Parallel structures, such as the Stewart platform [2], are well known mechanisms. The classic Stewart platform, shown in Fig. 1, consists of two plates joined by six links (also called legs). The lower plate is called base and the upper plate platform. The joints connecting the base to the platform are usually spherical joints. The main features of this kind of structure are: high rigidity; high precision and a good capacity to support heavy loads [3].

Thanks to these features, Stewart platforms are usually used as actuators in many fields of application, where high precision movements and a high pay load are required; for example high precision manipulators [5], radio telescope orientation [6], aircraft simulators [7] and machine tools [8], industrial vibratory bowl feeders [9].

Many works are available in literature on Stewart platform used as force torque sensor. Rees-Jones [10] and Kerr [11] were ones of the first researchers that proposed the use of a Stewart platform as a force/torque sensor. Than many studies have been done on this subject concerning the design, the performance and the application; as some examples: Nguyen et al. [12] analysed a Stewart platform-based force/torque sensor; Bicchi [13] studied the optimal design for a multi-axial force sensor; Dai et al. [14] proposed a new type of Stewart platform-based force transducer that is capable of giving information on the knowledge of the position of current contact points and of the magnitude of the contact force; Kaneko [15] proposed a twin-head type six-axis force sensor; Ranganath et al. [16] studied a high sensitive force torque sensor in a near-singular configuration in order to have a magnification in link forces; Sorli and Zhmud [17] investigated the performances of a multi-axial load sensor for robotic assembly hand and in another work [18] a sensor with adaptable performances; Dai and Kerr [19] described the design of a six-component contact force measuring device, for studying the forces found in robotic grasping; Ferraresi et al. [20] investigated the state and dynamic behaviour of a high stiffness sensor; Dwarakanath Bhaskar Dasgupta and Mruthyunjaya [21] investigated the influence of the size of

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