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Beam type hexapod structure based six component force–torque sensor

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ABSTRACT

The platform of a hexapod is a part of the structure whose six degrees of freedom are constrained by six linearly independent line constraints. The six line constraints are utilized for developing simply supported, "joint less" connector configuration for the transmission of axial forces. Six beam transducers are utilized to serve as a base of a hexapod structure. The applied wrench information is obtained by measuring the six forces on the beam transducers at the fixed base. The idea of "joint less" structure and beam transducers resolve issues of precision and sensitivity in measuring a very small wrench. The validity of the design is proved by developing a prototype sensor as well as conducting various experiments. The results of the experiments are discussed in detail.

1. Introduction

The hexapod based force–torque (F–T) sensors are evolving steadily since Gaillet and Reboulet [1] developed the first sensor of this kind based on the Stewart platform. Nguyen et al. [2] reported the development of a compliant Stewart platform based sensor with LVDT's mounted along the connectors for wrench measurement. In a hexapod, the six degrees of freedom of the platform is constrained with respect to the base by six line constraints. A line constraint is attained in a hexapod structure by connecting one end of the connector to the fixed base plate through a Universal joint and other end of the connector to the platform through a Spherical joint. Each line constraint is often referred to as an S–U kinematic chain. Six such constraints result in a Hexapod structure, structurally; they are stress decoupled connectors of the hexapod. The six spherical and six universal joints offer 18 and 24 constraints respectively. This poses significant complexity in manufacturing high precision mechanism with zero degree of freedom with zero mobility of the platform. Some research is directed in seeking novel design solutions to manage the compound joints at the connections points to achieve high accuracy. Efforts to do away with conventional joints are explored in many ways. Flexure joints at the connecting points are attempted [3,4] by exploiting the flexural property of some high strength material. The flexure joints in hexapod structure are difficult to manufacture because of the compound joints coupled with problems of accessibility constraints for machining. Dwarakanath et al. [5] reported development of "Simply supported" stiff force–torque sensor based on the Stewart platform. Hou et al. [6] proposes a hyper-static six-component force/torque sensor structure based on the Stewart platform. The greater part of research focus is directed to address the properties of the multi-component force–torque sensor. The geometry of the hexapod, the form of the connectors, various combinations of connection patterns at the platform and the base are all studied to maximize the twin objectives of isotropy and the sensitivity [7,8]. An attempt is also made to build the Stewart platform based Force–torque sensor at near singular configuration to enhance the sensitivity [4]. High sensitivity could be achieved only in two components of external force and one component of applied moment thus adversely lacking in isotropy.

The "Simply supported" stiff force–torque sensor based on the Stewart platform, given in Ref. [5] and shown in Figs. 1 and 2 explains, how the geometry of the hexapod is utilized to build a six-component force–torque sensor without any mechanical joints. The joint less parallel structure considerably simplifies the manufacturing complexities by doing away with six spherical and six universal joints thus resulting in a simple structure. Very high precision sensing is possible because of the absence of the mechanical joints. A spherical joint can replace the universal joint as it only imparts a passive degree of freedom to the connector and does not alter the degree of freedom of the platform. Therefore the platform can be constrained by six S–S kinematic chains. The joint less structure is highly portable and can be hoisted for temporary measuring purposes at various sites. The joint less arrangement provides larger scope for miniaturization of the system. However, measuring the force at the connector to reconstruct the applied wrench presents problems. The connector has to be designed to serve as a load cell, therefore the geometric form of the connector is very important and is optimized to enhance the sensitivity and

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