KINEMATIC ANALYSIS OF A NEW PARALLEL MACHINE TOOL: THE ORTHOGLIDE

P. WENGER AND D. CHABLAT
Institut de Recherche en Communication et Cybernétique de Nantes, France
email: philippe.wenger@ircyn.ec-nantes.fr

Abstract. This paper describes a new parallel kinematic architecture for machining applications: the orthoglide. This machine features three fixed parallel linear joints which are mounted orthogonally and a mobile platform which moves in the Cartesian x-y-z space with fixed orientation. The main interest of the orthoglide is that it takes benefit from the advantages of the popular PPP serial machines (regular Cartesian workspace shape and uniform performances) as well as from the parallel kinematic arrangement of the links (less inertia and better dynamic performances), which makes the orthoglide well suited to high-speed machining applications. Possible extension of the orthoglide to 5-axis machining is also investigated.

1. Introduction

Parallel kinematic machines (PKM) are commonly claimed to offer several advantages over their serial counterpart, like high structural rigidity, high dynamic capacities and high accuracy. On the other hand, they generally suffer from a reduced operational workspace due to the presence of internal singularities or self-collisions. Parallel kinematic machine tools attract the interest of more and more researchers and companies. Since the first prototype presented in 1994 during the IMTS in Chicago by Gidding&Lewis (the Variax), many other prototypes have appeared as could be seen during the last World Exhibition EMO'99 which was held in Paris in May 1999. A recent comparative study shows that certain parallel kinematic structures do have potential advantages over their serial counterparts (Wenger et al 1999). Despite this, it is worth noting that many users of machine tools are still not convinced by the potential benefits of PKM. Most industrial 3-axis machine tools have a PPP kinematic architecture with orthogonal joint axes along the x, y, z directions. Thus, the motion of the tool in each of these direction is linearly related to the motion of one of the three actuated axes. Also, the performances (e.g. maximum speeds, forces, accuracy and rigidity) are constant in the most part of the Cartesian workspace, which is a
parallelepiped. In contrast, the common features of most existing PKM are a Cartesian workspace shape of complex geometry and highly non linear input/output relations. For most PKM, the Jacobian matrix which relates the joint rates and the output velocities is not constant and not isotropic. Consequently, the performances may vary considerably for different points in the Cartesian workspace and for different directions at one given point, which is a serious drawback for machining applications. The orthoglide studied in this paper is designed in order keep the regularity of the Cartesian workspace shape as well as the uniformity of performances of the PPP machine tools, while taking benefit from the parallel kinematic arrangement of the links.

The organisation of this paper is as follows. Next section is devoted to the presentation of existing PKM and of the orthoglide. Section 3 investigates kinematic performances of the orthoglide. Possible extensions to 5-axis PKM of the orthoglide are discussed in section 4. Last section concludes this paper.

2. Preliminaries

2.1. EXISTING PROTOTYPE OR COMMERCIAL PKM

There are many possible types of PKM architectures which find applications in motion simulators, robotic manipulators and more recently in machine tools (Merlet 1997). In the context of machine tool applications, most existing prototypes or commercial PKM can be classified into two general families: (i) PKM with fixed foot points and variable strut lengths and (ii) PKM with fixed length struts and moveable foot points.

The first family comprises the so-called hexapod machines which, in fact, feature a Gough-Stewart platform architecture. Numerous examples of hexapods PKM exist: the VARIAX-Hexacenter (Gidding&Lewis), the CMW300 (Compagnie Mécanique des Vosges), the TORNADO 2000 (Hexel), the MIKROMAT 6X (Mikromat/IWU), the hexapod OKUMA (Okuma), the hexapod G500 (GEODETIC). In this first family, we find also hybrid architectures with a 2-axis wrist mounted in series with a 3-DOF parallel structure (e.g. the TRICEPT 805, Neos Robotics).

The second family (ii) of PKM has been more recently investigated. In this category we find the HEXAGLIDE (ETH Zürich) which features six parallel (also in the geometrical sense) and coplanar linear joints. The HexaM (Toyota) is another example with non coplanar linear joints. A 3-axis translational version of the hexaglide is the TRIGLIDE (Mikron), which has three coplanar and parallel linear joints. Another 3-axis translational PKM is proposed by the ISW Uni Stuttgart with the