

Parallel Positioning System Integrated Measurement Device

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Abstract

In this paper, a new high precision and high speed positioning system having integrated a measurement device for its tool center point (TCP) has been developed. The Parallel Positioning System (PPS) consists from a Parallel Kinematic (PK) motion unit – planar actuated, and Metrological device (Me) – tracker, able to work together in high dynamic manner (1 m/s speed, 10 m/s²) and accuracy (5 μm). An overview of the design concept together with the performance obtained for the first prototype built as demonstrator are presented in order to prove the idea viability.

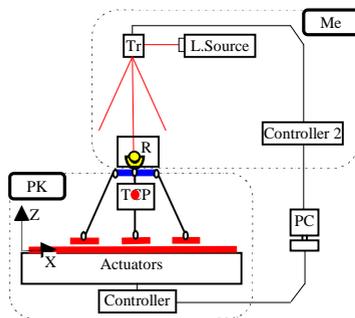
1 Introduction

Positioning one piece relative to another with high precision and/or high speed is a task required in many areas of industrial automation. Parallel Kinematic Mechanisms (PKM) already proved their capability to provide multi degrees of freedom (dof>3) dynamic performances for high precision tasks and in a compact package based on their intrinsic stiffness and compensation of errors feature. However, not usual for large workspaces; with few exceptions, e.g. when use planar motor actuation. The design, tests, calibration have been the topic of research for some R&D laboratories, e.g. [1], [2], etc. However, an integrated metrological system to direct measure the output motion, or tool center point (TCP) along and/or around all the 3D (6D) axes of motion - translation and/or rotations is missing up to now in this specific sector. An attempt was made in the past, for use with a microCMM, e.g. [2].

A new highly dynamic Parallel (Kinematic) Positioning System (PPS) with high accurate 6dof capabilities - large translational & orientation and having integrated a direct 3D(XYZ) measurement device working in above conditions has been developed in a frame of collaboration project (ProInno II) between Albert Ludwig Freiburg University (IMTEK) and private company (miCos GmbH)[3]. The results of the work have been materialized in a first prove of concept demonstrator (prototype).

2 Design Concept

In most of the PKMs cases, the EE position values are coming as (indirect) result of complex computations, involving fix and variable geometrical parameters. They are strong interconnected, and derived from the manufacturing and/or (sensors) measurements. As such, the TCP final value is under the errors prone. A more easy way to find out the real value could be by applying direct measurements: a) 2D(XY) or 3D(XYZ) on the laser interferometer principle have been a preferred solutions for semiconductor, optics and metrological products (e.g. stages [4], CMMs [5], etc). However, despite their high accuracy (nanometer order) and integration, the displacements and speed range of measurements are relative small, implying complex constructions and high costs; b) For large size 3D motion measurements, as machine tools, robots, etc the laser tracker systems have been used [6] . These are stand alone large size, heavy systems with low sample rate and high price.



Tracker

Figure 1: PPS with integrated measurements: a) concept and b) prototype

A feasibility study was performed in order to find out the best integration solution of a direct measurement device with planar actuated PKMs for a more general context of Desktop microfactory assembly/control tasks. The final concept is shown in Fig. 1. Parallel Positioning System (PPS) consists from a parallel kinematic unit(PK) and metrological device (Me) hold inside of a stiff frame. During the positioning tasks, the end-effector (platform) motion of PK its followed by a laser beam tracker (Tr) through an retroreflector (R) attached to it. Thus, the displacements of the tool center point (TCP) are measured highly accurate, continuously and direct. The entire work is supervised by two Control unit (C1,C2) and a PC where the data are managed (visualisation, analyse, etc) based on specific motion control software (LabView).

Parallel Kinematic unit (PK). Direct drive (DD) & air bearing technologies have already proved their advantages in precision and high speed applications; adopted for suitable PK structures can offer distinct advantages especially, for long strokes and large orientations. The PK consists from a classical [7] 6dof tripod structure: (PP)SR (Prismatic/Prismatic/Spherical)–PP actuated, optimum designed for maximum workspace, load and accuracy actuated by three(3) standard planar motors

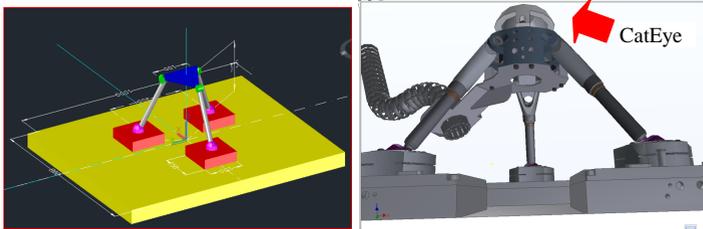


Figure 2: PK Unit (PK) : a) geometry and b) solid model

The motion along /around axes (XYZR_xR_yR_z) is coming as a combination of the forcers(F) highly dynamic and accurate XY motion on a large table(T),Fig.2 & Tab.1. A dedicated software (SpaceFab) was used to find and control the best geometry.

Table 1: Mechanical Positioning unit(Pu)

PKM	Type	Principle	Size [mm]	Material
Actuators	Planar (IDAM)	DD	T: 1100x700x50	Steel
		Airbearing	F: 184x154x28	Steel
Links	Rod	Hollow shaft	φ 25	Carbon fiber
Joints	R,S	Sliding	φ10, φ30	Steel/Ceramic

Metrological device (Me). Me is based on laser tracker measurement principle. It uses two angles and one distance to determine the movable TCP in space based on a smaller size retroreflector (R). In a compact modular design the tracker unit (T)

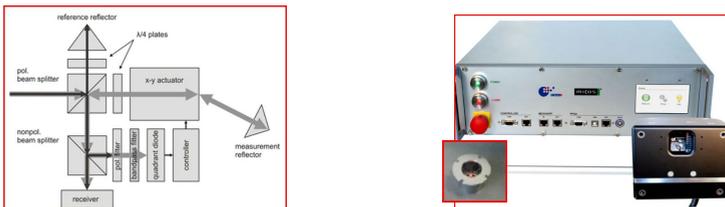


Figure 3: Metrological device (Me) : a) The principle and b) Components (Cat-eye, Tracker, C2)

includes a highly dynamic galvanometer scanner as actuator and several optoelectronic components arranged in a small box attached to the upper side of the

main frame (Fig. 3). The use of a small glass prism for R is a robust, cost effective solution; its accuracy is important in the error budget [8]. Control unit (C2) is a hybrid (PI/microcontroller) made from standard components (low cost). A software is supervising the measurement process, by optimizing the necessary parameters and then visualized them on an integrated touch display. High speed monitoring and data transfer are possible through RS-232 or USB interfaces. Main performances are included in Tab.2; others features: automatic search algorithm in the case of a beam loss, absolute distance measuring technique for online adaptation of the controller parameters, etc.

Table 2: Metrological device(Me)

Type	Source [nm] / m	Size [mm]	Rate [kKz]	Weight [kg]	Volume [m] / [°]	Speed [m/s]	Accuracy [μm]
Tracker (Interf.+ Galv.sc.)	λ:632,9 φ :3 @ 1	L:190 B:120 H:160	37	Tr:5,4 C:15,5	R:10(30) A: ±20	R: 0.7 L: 1	Res: 6 Rep: 8

R-radial, A-angular, L-lateral

3 Conclusion

An innovative parallel positioning system with integrated device for direct measurements was proposed and built. Based on first analysed data its performances (Tab.3) recommend it as high precision and high speed positioning system, e.g. tabletop assembly, quality control operations, etc fulfilling the scope of the work.

Table3: PPS Features

Typ	Size [m]	XYZ [mm]	RxRyRz [°]	Load [kg]	Speed [m/s]	Acc. [m/s ²]	Rep. [μm]	Res. [μm]
PK	2,2x1,5x1,1	550x240x40	15x15x150	5	1	10	5	0,5

Further improvements consists in developing a device for 6D axes of motion measurements (3T+3R), an actual BMWi/BMBF project. Additional, the implementation of Ethernet control interface is envisaged.

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