Precision positioning device for X-ray spectroscopy

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Abstract

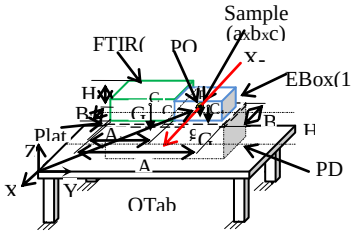
An application specific development of a multi-axis precision positioning device (PPD) for spectroscopy research using synchrotron X-rays is presented. Based on an arrangement of sample (cell) & instrument (FTIR), together with weight, motion and position accuracy requirements, the design concept and manufacturing technology are briefly described. The new architecture is based on an asymmetric 2dof (Z, Rx/Ry) spatial parallel kinematic (TRIGLIDE) module having three different kinematic chains, but identical vertical actuators (Z-stages) supporting a serial stages module (X, Rz). By their simultaneous control, the platform is providing a position, stiffness and accuracy by using only standard precision components for cost and time saving.

1. Introduction

Advanced techniques for in-situ investigation of cathalytic materials using X-ray tools is constantly increasing in interest [1]. Using a synchotron X-ray tool, the physical and chemnical properties of a structure are analysed for a variety of samples under specific realistic conditions and in real-time (e.g. active catalysts). In this respect, the samples & specific instruments have to be manipulated in the desired positions with precision, last for a while or continuosly moved (scannning mode). However, the machines, systems or *positioning devices* designers have to cope sometimes with a set of requirements, often contradictory, regarding the existent shape/available space, weight /precision or, time delivery/costs. An example of a succesful management of all of these together with the obtained results for such a working device built for a research laboratory (KIT/ITCP/IKFT) [2] using a synchotron beam line facility (ANKA) [3] and performed by a *specialized company* (HUBER GmbH&Co.KG) is given.

2. Design Concept

The design of a multiaxis Precision Positioning Device (PPD) requires good management of mixture of *know-how* and *expertise* from precision engineering area in order to cope with sometimes fast and cost-effective design, or 'real-time' delivery. *Requirements.* An experimental device, e.g. cell reactor sample (Sp) inside of an experimental box (EBox)-1 has to be analysed during a periode of time through a stationary X-ray. Data being recorded by a Fourier Transform Infrared (FTIR) spectrometer-2, all components are to be supported on a plate (Plate) and moved in a particular way by a Positioning Device (PD) fixed on an optical table (OTable), Fig.1.



Tab.1

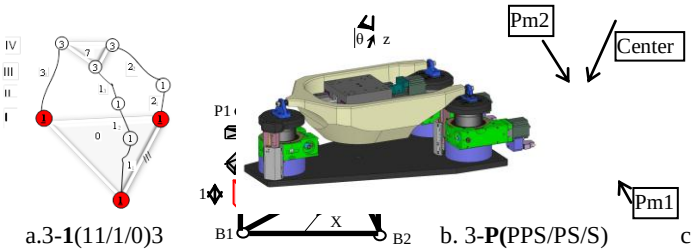
Part	A_i(a) [mm]	B_i(b) [mm]	H_i(h) [mm]	G_i [N]
Sp	8	30	1	10
1.	610	410	150	150
2.	665	420	200	400
Axes	X [mm]	Z [mm]	Rx(Ry) [°]	Rz [°]
Sp,1,2	50	50	±6	±30

Fig. 1: Geometry & Motion

The PD has to be fited in the available space (AxBxH=1280x440x250 mm) and the platform moved in space (X,Z,Rx/Ry,Rz) with a predeterminated motion; strokes and accuracy, Tab.1. (P (272,170,150)- Point of Interest (POI), C_i-geometrical centres, C-platform center, accuracy=10 µm /X(Z); 2 mrad/ Rx(y,z)).

Mechanism. For load, precision and available space point of view, a parallel kinematic solution [4] has been choosen first, as a main module; and, for some values of strokes (e.g. Rz) reasons an additional serial one. This hybrid combination (parallel/serial) has been envisaged to be built with the already existent/on the shelf standard components (e.g. stages, joints, etc) from inside the company, for time & costs saving. As the available height (H) has been quite small, a TRIGLIDE spatial Parallel Kinematic Mechanism (PKM) with three vertical prismatic actuators (**P**) located on the base, as vertical jacks (using, Z-stages), together with (commercially) available compact Spherical joints (S) was a suitable choice instead of a classical TRIPOD (3-3UPU or 3-3PUU) one. However, as in the topological structure (3-**1**(11/11/0)3, f=1, 3- dof /joints, 1_i,2_i,3_i – elements, i-Kc number) Fig. 2a is shown, even if the number of mobile elements are the same (7) the kinematic chains (Kc) **P**PPS-**P**PS-**P**S (P/**P**–un/actuated are ⊥), Fig.2b are slightly different. The additional

2dof (X, Rz) on top is coming as a serial arrangement (P‖R, vertical axes are coinciding), Fig.2c.



a.3-**1**(11/1/0)3 b. 3-**P(**PPS/PS/S) c. 3D (PKM/SK)

Fig. 2: Kinematics & CAD

Tab.2

Module/Unit	Motion	Mechanism	Type	Prec.
Pm1	Z,Rx,Ry	PKM	TRIGLIDE	-
a. Pu11-13	Z	Jacks	5013.A90	±3µm
Pm2	X, Rz	SK	Stacked	-
a. Pu21	Rz	Worm-gear	411	40”
b. Pu22	X	Ball-screw	5101.30	±4µm

Design. A modular but fully integrated mechatronic approach has been adopted. It consists of a mechanical Positioning Device (PD), a Controller unit(C) and Software (SW) means (see also, Fig. 4). The PD is based on parallel Positioning module (Pm1) holding inside of the deeply caved Platform (P), the second Positioning module (Pm2) formed as a combination of linear/ rotation stages, Tab.2. Pm1 has been built of stiff and reliable individual Positioning units (Pu11-Pu13) using heavy load precision Z-stages including a stepping motor (VEXTA/PK266-02B), worm-gear transmision, hollow/threded shaft/nut, ball bearing, external sliding/guiding system, incremental linear scale (TONIC,0.5µm) and limit switches. The Pm2 is consisting of a Translation table (411) and a Rotation stage (5101.30). Pu11 (12,13) are each connected to the platform through identical sliding spherical joints (GE8-PW/SCHAFFER) and five ball-bearings (MLF14/IKO) linear guides. Proprietary manufacturing and assembly processes assure that the standard precision (X1) is obtained for all motion stages (Pu11-Pu22)[5].

Modelling&Simulations. A brief overview of PD working behaviour by taken in to account the only PKM module is shown in Fig. 3 (X=0, Rz=0).

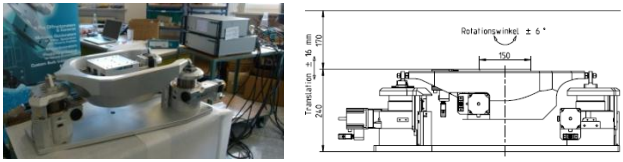
The displacement parameters values (φ,θ) of the platform are interdependent. And, the maximum numerical values (φ=6°) is obtained at the price of substantially afecting other (Z=±16mm).

a.Tip (φ=6°) b. Tilt (θ=6°) c. Lift (Z=25mm)

Fig. 3: Extreme positions

3. Prototype

A prototype based on above design concept and technology has been recently finished. It includes the described Positioning Device(PD), driver & controll unit (C9100/9305) and software (PC) means to work together. The first tests (sequential mode) shows the expected capability of the system. Fig.4 depicted the PD in nominal position (Z=240mm) with some general features.



a. Tests b. Dimensions

Fig. 4: Working Prototype

4. Conclusions

An application specific multiaxis Precision Positioning Device (PPD) prototype has been acomplished on the requirements based on PKM(TRIGLIDE) module. The paper described the conceptual design process, emphasizing on multidisciplinary approach and specific technology used. The robust, reliable and compact mechatronic product presented stands as other PKMs based precision positioning solution for research industry at reasonable costs.

References

[1] Schroer,C.G.&Grünwald,J-D.,In situ characterization of heterogenuos catalysts, JW&S, ISBN: 97811180000168, 2013.
[2] ***KIT/IKFT, http://www.ikft.kit.edu/319.php, March 2014.
[3] ***KIT/ANKA,http://www.anka.kit.edu,March 2014.
[4] J-P. Merlet, Parallel Robots, ISBN-10 1-4020-4132-2, 2006 (Sec. Ed.).
[5] *** HUBER GmbH Co.&KG, Product Catalogues, 2010.