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Accuracy of positioning for a table device

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Abstract

We report about the accuracy of a parallel positioning table device conceived to perform high precision positioning tasks in synchrotron environments. The newly developed device consists from a set of four planar actuated modules (Ac) having 2dof each, supporting two another ones, the elevation (El) and guiding(Gu) stacked positioning units, respectively. Built for the first time using high precision XY stages, this special arrangement principle (OCTOGLIDE) is expected to provide an alternative solution for positioning samples (and, instruments) inside Diffractometer (Dm) machines by minimizing the volumetric errors. For a testing prototype, a complete set of precision measurements has been performed. In order to be able to characterize its positioning accuracy the measurements consisted in both, the linear and rotational motions, respectively. The measurement process including the methodology, instruments and the setups to cope with the expected precision is shortly presented. The numerically and/or graphically values were finally analysed. The obtained experimental results provided more insides into the motion error aspects, opening the way for further improvements.

Parallel kinematics, Positioning, Accuracy, X-ray

1. Introduction

Synchrotron research is an actual increased field of research. By using standard (or, advanced) X-ray diffraction techniques, the material structures can be deeply investigated. The actual new facilities benefit of powerful and precise tool (light) and the applications are spaninng from engineering, to natural science, up to the medical ones. However, the final results are in direct relation with the precision of machines, instruments and devices used.

The dedicated machines (Diffractometers), e.g. [1] must fulfil the specific requirements of the physical process. Inside, the specific instruments and/or devices must work together with the imposed accuracy in order to accomplish the task. The samples (and instruments) are very often positioned with a set of linear/angular precision positioning devices based on a succession (series) of simple stages materializing one of the motion axis (X,Y,Z), e.g. [2] or Parallel Kinematic (PK), e.g. [3] concept where the motion axis are acting in-parallel. The most prominent typ of PK class are Hexapods. They provide a good compromise of high performances regarding the accuracy and load manipulated. But, they are still in a few number of standard typo-dimensions and by this, sometimes difficult to fit inside.

As an alternative solution, a new concept has been proposed. After the first prototype has been finished and the first investigative results revealed a promising future, the complete accuracy of this device is investigated here. It includes the methodology and strategy to perform the measurements and the specific setup used. Finally, the results are analysed.

2. Device

A new concept for a parallel positioning table device has been proposed [4]. It is based on OCTOGLIDE redundant principle. Beside of its compactness(height) and simplicity of motion advantages being more powerful - specific to diffraction applications, comparing with its counter parts (serial and/or parallel) it is expected to perform high precision tasks also, by minimizing the resulted motion errors.

The Redundant Positioning Table Device (Rd-PPTD) prototype was built with a set of four high precision XY stages (5102.15/XE [2]) - X/Y=±25mm, A=±0.1μm, R=±0.1μm, Straight / Flat= 3μm supporting the classical linear rolling guides for elevation (EL) and customized spherical sliding joints for guiding (Gu) positioning units (Pu), respectively.

By this arrangement, a 6 dof motion is observed with easy along/around the Carthezian axis. The maximum values of the traveling range are: X=Y=50mm, Z=29 mm, Rx= Ry=11°, Rz=18°. The overall dimensions are included in Fig. 1.

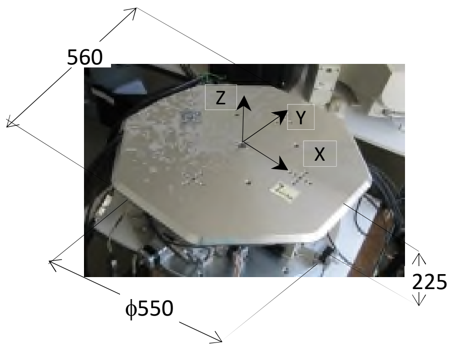

Figure 1. Redundant Parallel Positioning Table Device (Rd-PPTD)

The working behaviour and specific capabilities including the (preliminary) precision tests of accuracy and stability have been previously reported [5]. However, the few measurements performed under some incipient specific conditions (Z axis, open loop control, SJ plastic houses, etc.) given us a first but small flavour of its expected precision, only.

3. Measurements

In order to finally characterize a new positioning product, a set of specific features (accuracy, stability, etc.) must be investigated. Under initial conditions, these can be theoretically evaluated or experimentally determined before the mass / series production starts. In the last case, the process imply to choose a strategy, to define a methodology and to use the adequate instruments/devices.

For Rd-PPTD, the actual measurements have been done with some improvements compairing with previously ones:

a) The real (steel) spherical joints (SJ) have been used

b) The closed loop mode implemented.

However, in order to prevent the over constrained unpleasant consequences which would have appeared during the measurement process: a) the second part (down) of the SJ houses were intentionally kept free (instead, a small/12 kg load on the table corresponding to each of them applied) and b) each measured position was manualy introduced. The device was necessary to move (mannually) to the zero(nominal) position each time a new type of measurement starts.

3.1 Methodology

The measuring process consisted in to perform two (2) sets of measurements. Each of them corresponding to different types of motion axis, which attracted implicit different arrangements (setups).

The first (1) one imply the horizontal (X) and second (2) the vertical (Z) axis, respectively. In each of them, the interferometer position changed accordingly. The measured deviations (errors) have been registered for both: a) linear (X, Z) and b) rotational (Rx, Ry, Rz) basic motions, by following a set of three (3)-2σ traveling motions (ISO 230 [6]) in positive and negative directions. An overview of the max/min limits are given in Tab. 1.

Table 1 Positioning Motion

Type	Axis	Stroke	Unit
Linear	X, Z	±20, ±12	mm
Rotational	Rx,Ry,Rz	±5,±5,±5	°

3.2 Setup

The measurements have been performed in a dedicated metrological room using standard tools (instruments) and devices (table). In addition, an auxiliary frame (support) was necessary to be built. This setup for both, X-axis and Z-axis, respectively is presented in Fig. 2. It includes:

a) The granit base (1) with additional frame/ Z axis (2)
b) Table positioning device (3) whose motion has been measured,
c) The HEWLETT-PACKARD [7] interferometer (4) who performed the measurements.

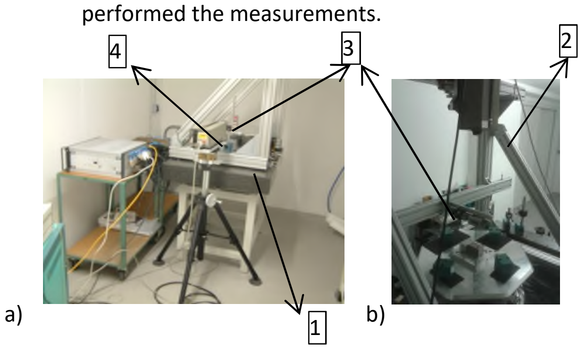

Figure 2. Measurment setup: a) X-axis and b) Z-axis

3.3 Results

By following the above measurement strategy and methodology, an appreciable number of results – numerical and graphically data have been obtained. By their analysis, the complete motion accuracy (linear and rotational) in positioning for Rd-PPTD was possible to be characterized and the errors identified. For example, for positive directions (+) the errors diagrams in: a) linear (X and Z) and b) rotational (Rx,Ry,Rz) motions are included in Fig. 3 and the numerical values in Tab.2, respectively.

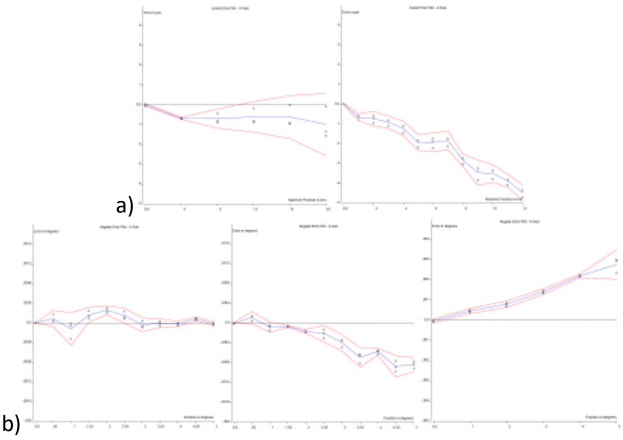

Figure 3. Positioning accuracy: a) Linear(X & Z) and b) Angular(Roll, Pitch &Yaw)

Table 2 Positioning **a**ccuracy (linear&angular)

Param.	X [µm]	Z [µm]	Pitch [°]	Roll [°]	Yaw [°]
Acc.(A)	3,162	4,918	0,00132	0,00080	0,00361
Rep.(R)	3,162	1,276	0,00043	0,00066	0,00143
SysD(E)	0,990	4,488	0,00098	0,00038	0,00279

As can be seen from above, the positioning motion is performed with some errors, in both the incipient and final stage. We believe that the main source are coming from the mechanical (backlash, stick-sleep, etc) and/or the primitive control strategy (software) applied which must be solved in the future.

4. Conclusion

For a Rd-PPTD, a complete test of accuracy in positioning has been experimentally done. It gave us a good overview of its capabilities and the improvements necessary to be done.

By analysing all the data in positive and negative directions respectively, we conclude that the device can work in linear/ angular motions with an absolute accuracy of ± 5 μm / 6.5 arcs and repeatability of ± 3 μm/ 5.5 arcs.

Further work is consisting in to investigating the possibilities to increase the accuracy by using an improved motion control strategy and kinematic calibration procedures implemented through an automating measurement process.

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