Precision Heavy Load Alignment Bases

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Abstract

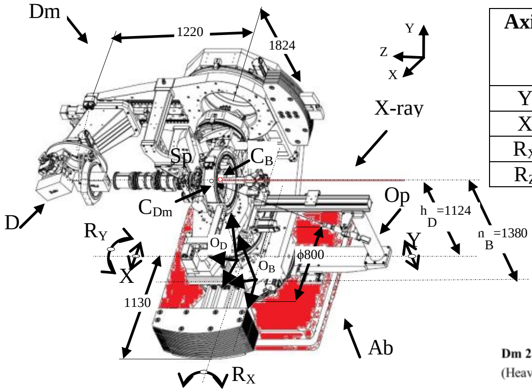
The specific development of a positioning system to manipulate heavy loads with high precision in synchrotron facilities for alignment purpose is presented. The proposed Alignment Base (Ab) is an innovative system providing the necessary shape, stiffness, accuracy and flexibility to support and to precisely align two types of Diffractometers and related instruments within short settling time for stable and reliable X-ray investigations motion. The hybrid structure is built around a 2 dof (Y, R_X) Parallel Positioning Module (P-Pm) based on two pairs of simple (1dof) Positioning units (Pu) with standard components and customized precision.

1 Introduction

Precision multiaxis positioning systems are common to many micron industries and related research processes (semiconductor, photonics, mechanical, etc). An appreciable number of such products are working in synchrotron facilities, as well. There is quite a large variety of types and dimensions depending on applications. *Alignment Bases* (Ab) dedicated to Diffractometers (Dm) provides support and up to 6 dof displacement motions for the alignment of the machines with the X-ray incoming beam. As Dm could reach sometimes tons and the motion necessary to be performed are fast, Ab must be robust enough to cope with their dynamics, insensitive at various environmental factors (temperature, vibrations, etc) and stable as the required position could last. Several companies are producing such products upon different principles (e.g. NEWPORT, HUBER, KOHZU, ADC, etc). HUBER GmbH & Co. KG.[1] offers a large pallet of standard and customized reliable alignment bases on customer's specifications. An example related with the newly developed project (I07/DLS [2]) is described here.

2 Design Requirements

The I07 Diffractometers (Dm1&Dm2) have been developed to investigate the atomic structure of materials (surface/interfaces) using specific diffraction techniques (GIXD, GISAXS, XRR)[3]. They are complex heavy equipment, where the correlated motions-Sample(S), Detector (D) and the additional Optical instruments (Op) with the incoming X-ray beam must be with high precision [4] performed relative fast and for a desired position to stay longer time(days). In order to achieve all these, several *alignment processes* are to be done. Briefly, they consist in coinciding the Dm (virtual) center (C_{Dm}) with that of the beam(spot) center (C_B); or, at least no far then an acceptable error interval (sphere of confusion/SoC). Initially, before the first X-ray investigations even start, Dm longitudinal axis should be aligned with that of the X-ray beam, Fig.1 soon after are fixed along beam.



Axis	Stroke [mm] [°]	Res. [μm] [m°]	Acc. [μm] [m°]
Y	±50	1	±2
X	±50	2	±5
R_X	±1	1	2
R_Z	±2	5	5

Res-Resolution, Acc- Accuracy

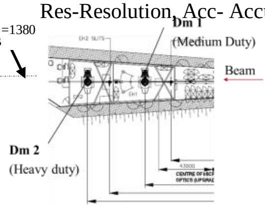
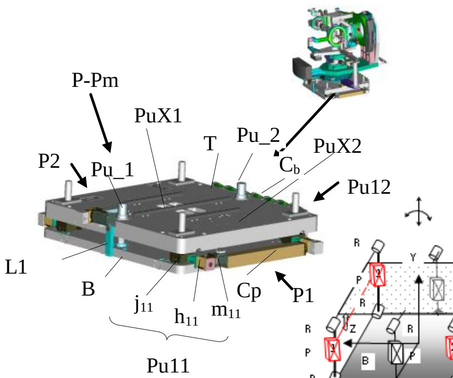


Fig.1 Alignment base (Ab) - Geometrical & Motion Specifications

The alignments process includes: (a) roughly and (b) fine displacements.(a)The table is sent in 0 position (zero point); motion parameters are *initialized* and geometrical parameters and errors (e.g. table horizontality) checked by using standard metrological devices (bubble levels).Then the table is set to *nominal position* (h=256mm), using h_B, h_D - Xray beam, Dm heights; the coincidence with h_B verified with optical devices (laser theodolite). Finally(b), the table will be moved in a dedicated fixed position inside of the range(Y/X=±50mm) for X-ray investigation. During these steps (setling and final) several precision motions are to be done (X,Y,Rx,Rz), Z-beam axis; the required range and accuracy are included in the table.

3 Conceptual Design

A system providing all requirements from above (dof, stroke, accuracy) for approx. one (1) ton eccentric dynamics load must be stiff enough, precise and if possible flexible/reconfigurable (for two Dm) for costs reasons. A *Parallel Kinematic*(PK) architecture could cope with [5]. The *basic* topology consists from a planar 2(1**1**1)-11 (**1**-actuated pair) multiplied twice in space. The symmetrically 2-2(R**P**R)-PR geometry of the *mechanism*, Fig.2 comprises two(2) active RPR (coupled) and two passive PR (pillars) kinematic chains (R-revolute, P-prismatic) delivering 2 dof (Y,R_X). Two other simple linear motions/1dof which direct and/or indirect contribute to the alignment (X,Rz) completes the hybrid structure.



No	Pm/Pu	Axis	Type	Drive
1	P-Pm	Y,Rx	PKM	Motor
a.	Pu11,...,22	Y	Jack	Motor
b.	Pu1_Pu14	Rz	Feet	Manual
c.	Pu_1/Pu_2	Y	Shaft	Pasive
2.	PuX1	X	Guide	Motor
3.	PuX2	X	Guide	Manual

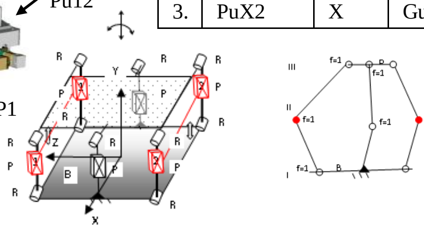


Fig.2 Design (CAD&Integration) and Kinematics Principle (Geometry&Topology)

The *design concept* has been adapted to the scope; it consists from a *modular approach* built around the Parallel Positioning module (P-Pm). It includes a stiff base (B) and flat table (T)-moved by: a) two pair (P1,P2) of motorized-active (Pu11/Pu12; P21/P22) and b) passive (Pu_1/Pu_2) Positioning units (Pu). Each of single active Pu comprises: a) actuation-motor(m), b) transmission mechanism-gearheads (h11-5:1), jack units (j11,p=6mm) and c) bolted joints(bushes) which are coupled with a bar (Cp). Some components are slightly modified from commercial ones for an increased stiffness and/or precision. P-Pm includes also two types of linear (L) and angular (A) limit switches. On the top of the table, two Pu (PuX1&PuX2) along X axis are integrated. *PuX1* is consisting from three linear guides and double carriages assuring the precise and stiff Dm motion through its 480 Goniometer(Gm) base. *PuX2* is a linear unit providing stiff removable optical rail (500 mm) motion mount for optical components to link their movements and the sample/detector. In addition, the *alignment telescope* with a field of view of 3-6 mm, a cross-hair reticule and a fine alignment system allow the telescope to be aligned with the centre of rotation through a CCD camera. Whole Ab system is positioned on the floor with several manually screws driven Positioning units (Pu1-P14)–14 feet, helping (small) orientation around Z (Rz) direction. 33 motion axis (3 of Ab) are interfaced to the controller in a *connector's box (Cb)* and the cable management done through several central holes. Four (4) stiff removable *Transportation (Tr)* means and *Protection cover* (Pr) are provided for easy and safety installation, Fig.3.

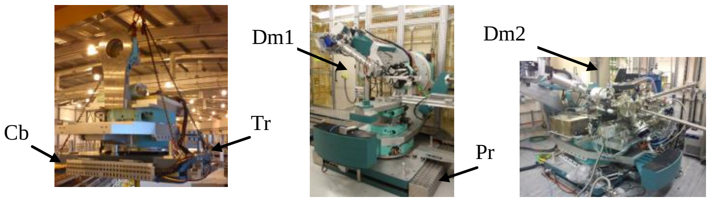


Fig.3 Alignment base(Ab) Installation and Working places (EH1/EH2)

4 Conclusions

Many factors contribute to the correctness, performance, and precision of X-ray investigations with diffractometers. One of the factors is their alignments and angular calibration. Improper alignment may cause distortion of the results. The diffractometers being complicated equipment, the alignments are not easy; it requires adequate precision systems and methodology. A proposal has been presented based on the advances and accumulated experience in positioning technology inside of the design for precision (DfP) concept. The product has been installed, tested (Dm together), being fully functional and with the parameters inside of the specified range. With minor modifications the product can be adapted at other similar purpose tasks.

References

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