Precision Hexapod – Preliminary CAD (A Work for Micro)

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Abstract

An overview of the results and the technology applied to cope with the specific problems of a precision hexapod design, able to work inside of a synchrotron end-station by carrying out micro positioning tasks are presented in this paper. In a previous work done, several solutions to choose the final geometry were proposed, after a systematic modelling&simulation analysis. However, the mechatronic components were taken in to the account only based on some of their static, dynamic or dimensional features (force / stiffness /displacements, etc). Here, more details are given as resulted from a CAD process performed. The hexapod layout, its integration, the actuators and joints implementation, as well as the specific manufacturing or assembly problems encountered and their solutions.

1 Introduction

Micro/nano technologies are advancing. More and more precise tools are necessary for investigations, manufacturing, test and/or control operations in the research area. Subsequently necessary devices, instruments and systems are becoming increasingly precise. A synchrotron machine is using an X-ray tool to 'penetrate' various materials. By manipulating a sample, an hexapod (HXP) has to move (pose) the sample in different locations as part of a difractometer instrument (Df). Specific conditions have to be fulfilled regarding the motion (and, poses) in the small scattering process (e.g. GISAXS, etc), Tab. 1.

2 Design

A methodology to manage the interconnected hexapod parameters and their contradictory influences on the workspace, stiffness and accuracy was taken in to account the customer requirements [1]. It revealed the strongly repetitive character of the design cycle: [ref. geometry]-[modification parameters]-[analyse]- [results interpretation of]-[new structure]- ...and back, and again. The amount of data manipulated was consistently. Several design parameters for components were taken in to account, too. In order to have a good feeling and feedback, a CAD design process was set up in parallel. The main steps and results are presented bellow.

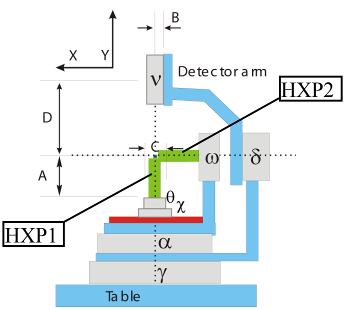
Table1: HXP’s working and design parameters required

Op./ Param.		Symbol/Unit	EH1 (HXP1)	EH2 (HXP2)	Note
Mounted		α [deg]	0 ; 90	90	Vertical/Horiz.
Fixed	Height	h [mm]	250 (<270)	250-300	Min. of stroke
	Base	R [mm]	350 (max)	350 (max)	Or, less
	Platform	R [mm]	200	200	Aprox.
	Hole	d1 [mm]	90	90	Aprox.
Motion	Translation	XYZ [mm]	25,15,25	15,25,25	Bi-directional
	Rep.	e_{tx},e_{ty},e_{tz} [µm]	±3, ±2, ±3	±2, ±3, ±3	Bi-directional
	Res.	□t[µm]	<1	<1	Less
	Speed	v [mm/s]	1	1	Max
	Rotation.	RxRyRz[dg]	10,20,10	20,10,10	Bi-directional
	Repeat.	e_{rx},e_{ry},e_{rz} [µm]	±40	±40	Bi-directional
	Resolution	□r [µrad]	<10	<10	Less
	Speed	ω [deg/s]	0.5	0.5	Max
Loade	Mass	m [kg]	50 + 30	30	Max.
	Distance	dG [mm]	150	150	Max.

(EH- Experimental hutch)

2.1 Integration

The hexapod interconnection was one of the first step to take in to account. Some of the parameters defining its location in the difractometer instrument enviroment are presented in Fig. 1 and Tab. 2, where A-sample distance (HXP1 in nominal position+sample center distance), and C-max. hexapod envelope (including the effective workspace).



Tab.2: HXP integration parameters

A [mm]	B [mm]	C [mm]	D [mm]
420	50	500	min.350

Figure 1 Hexapods location (difractometer)

The hexapod should not add significantly errors to the sphere of confusion (30 micrometers), neither by its movement or arrived in the chosen pose and staying there for longer time. For a fast, accurate and stiff reproducible positioning in both locations/ orientations (V/H) the hexapod was designed to be mounted on the difractometer [4] stages surfaces, by a pair of three pins and screws.

2.2 General concept

The results and conclusions from the first design analysis - design work for specification (DWS) were the base for the first step in to an effective design (CAD). With other words, the customer approved H3 geometry, Fig. 2 and Tab.3.

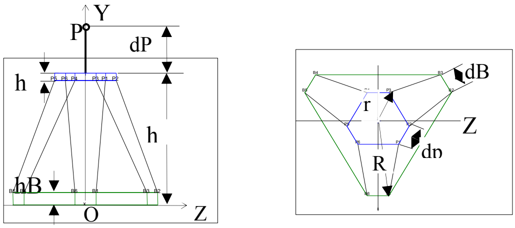


Figure 2: H3 geometry

Table 3: H3 parameters

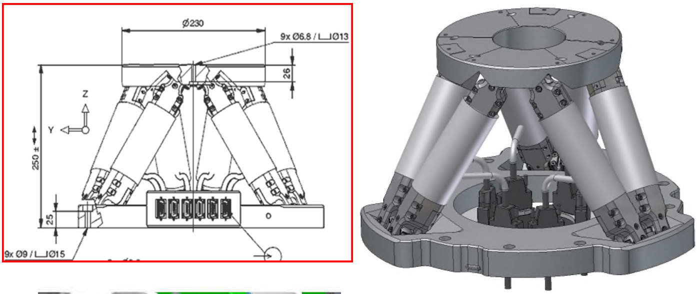
HXP	r [mm]	R [mm]	lmin [mm]	dl [mm]	dB=dp [mm]	dP [mm]	hB/hp [mm]	h [mm]
H3	80	180	230	35	41	170	25/15	251.3

The design solution is following the high stiffness and accuracy concept, based on mechanical computations, estimations performed, own and others experience.

2.3 Components

A completely integrated solution for the actuators - motor (FAULHABER), screw (INA), and sensors was chosen. By using at the limit the available inner space they are delivering a compact and stiff motion. The chosen components were based on the values of parameters resulted from mechanical, electrical and control computations - force/speed and /or accuracy.. Special attention was given to the stiffness and accuracy values limits. The joints are one of the week point in an hexapod design. In our design Universal joints are using standard needles (cost down). A selection procedure have to be applied in order to minimize the errors. They are deeply integrated in the base and platform structures and fixed with pins and screws. The base and platform are made from Al and legs (actuators) frame from steel.

a)



b)

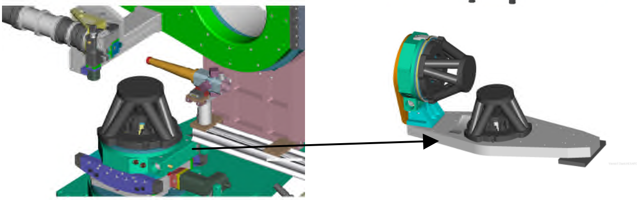


Figure 3: a) Hexapod HP-430(2D and 3D) CAD model and b) integration

3 Conclusion

To cope with the various multidisciplinary issues, a concurent mechatronical aproach was applied to design a precision mini hexapod. It included the systematic analysis of mechanical, electrical and control factors and actions towards the minimization of the possible motion & geometrical errors (work for micro). The adequate solutions chosen, by involving high precisely manufacturing operations (machining, assembly and quality control) in accordance with the type of material was done with 'an eye' to the costs. Whenever it was necessary, the computations were performed (MathCAD) and the solution verified (Autodesk INVENTOR and MSC/SimXpert). The own previous experience acquired by the company [2] and others [5] dealing with similar products was a definitely advantage. As the prototype is almost finished, and the first tests and conclusion proved that the results are in accordance with the estimations, this work can be considered as successful, and it could be adopted by others, too.

References:

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[5] Neugebauer R. - Parallelkinematische Maschinen ..., 2006.

[6] G. Olea - PMDB (Parallel Mechanisms Data Base)-Collection of best results,1938-2009.