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SOLARIS 3-Axis High Load, Low Profile, High Precision Motorized Positioner

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Abstract. A 3-axis optical table, shown in Figure 1, was designed, fabricated, and assembled for the SOLARIS synchrotron facility at the Jagiellonian University in Krakow, Poland. To accommodate the facility, the table was designed to be very low profile, as seen in Figure 2, and bear a high load. The platform has degrees of freedom in the vertical (Z) direction as well as horizontal transversal (X and Y) directions. The table is intended to sustain loads as large as 1500 kg which will be sufficient to support a variety of equipment to measure and facilitate synchrotron radiation. After assembly, the table was tested and calibrated to find its position error in the vertical direction. ADC has extensive experience designing and building custom complex high precision motion systems [1,2].

(a) (b)

FIGURE 1. (a) Computer assisted design model of the 3-axis platform (b) actual 3-axis platform

FIGURE 2. Overall height of motorized positioner (low profile)

Specifications

Each of the motorized stages has a normally closed limit switch. For vertical and horizontal transversal directions of motion, a linear encoder and zero position markers must be provided. The three axes of motion are supported on THK rails. A NEMA 23 stepper motor in combination with a planetary gearbox serves to drive the table in each direction of motion. All three motors drive a ball screw and are equipped with adjustable limit switches that can change the motion within the maximum range of travel. The specifications of the system including range of motion, resolution, weight, and load data are presented in Table 1.

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TABLE 1. Key specifications of the 3-axis platform

Description	X-Axis (horizontal)	Y-Axis (horizontal)	Z-Axis (vertical)
Range of Motion	+387mm/-387mm	+20mm/-20mm	+12.5mm/-12.5mm
Resolution (unit/step)	5 micron/full step	1.1 micron/full step	0.1 micron/full step
Minimum dynamic load capacity		1500 kg	
Estimated System Mass		993 kg	
Encoder Manuf.		Renishaw	

Following design, fabrication, and assembly of the system, a test was performed to assess the accuracy of the platform's vertical motion control. The system was loaded appropriately, and the Keyence high accuracy optical micrometer was controlled with a stepper motor controller and used to take the measurements associated with the system's mechanical repeatability. This data is tabulated and presented graphically in Table 2.

TABLE 2. Mechanical repeatability data for the 3-axis platform

Mechanical Repeatability Test Record

FORM-00009 Rev1.6, 2015-01-29

Measurments taken using the Keyence high accuracy optical micrometer, controlled using a stepper motor controller.

			Device Name	3 Axis Platform
Microstepping	64	ustep/step	System Serial Number:	150624-1
Run Velocity	1000	(steps/sec)	Job number:	14-044
Accel. & Decl.	1000	(steps/sec*sec)	Test Date	6/24/2015
Steps Made per Move	30000	steps/position	Open or Closed Loop?	Open
Motor Current Rating	4.2	Amps		
Run Current	1.5	Amps	Description Text in Yellow	
Controller % Hold Current	24	%	Entered data in Green	
Hold Current	0.36	Amps	Calculated values in Blue	
			Grey is unused cells	

Z Axis -

Position	Actual measured move (mm)						Uni-Directional error	Bi-Directional error
	+ direction 1'st pass	- direction 2'nd pass	+ direction 3'rd pass	- direction 4'th pass	+ direction 5'th pass	- direction 6'th pass		
1		29.7548		29.7559		29.7567	0.0019	
2	26.7640	26.7603	26.7647	26.7612	26.7641	26.7614	0.0011	0.0044
3	23.7781	23.7747	23.7788	23.7764	23.7792	23.7764	0.0017	0.0045
4	20.8107	20.8085	20.8111	20.8089	20.8117	20.8093	0.0010	0.0032
5	17.8452	17.8435	17.8456	17.8437	17.8461	17.8443	0.0009	0.0026
6	14.8943	14.8926	14.8958	14.8928	14.8955	14.8930	0.0015	0.0032
7	12.7080		12.7086		12.7082		0.0006	
						Positioning Error (RMS)	0.0013	0.0037

Finite Element Analysis (FEA)

Before actual assembly, the system was tested virtually with FEA techniques. The main platforms were tested under a load of 1500 kg to obtain a realistic model of the maximum load case for the specifications for this table. All deformation values from the FEA testing are within tens of microns order of magnitude. The theoretical deformation spread for the various positioning plates are presented graphically below in figures 3, 4, and 5.

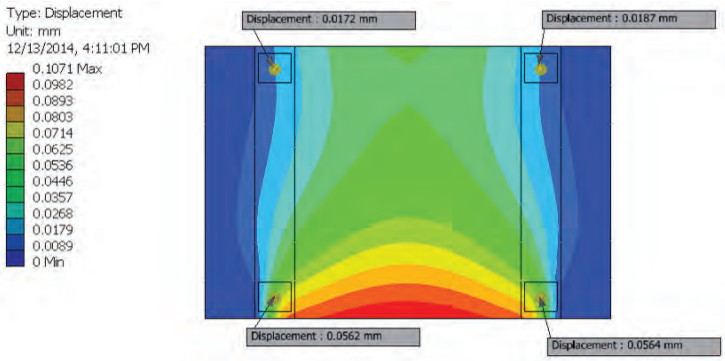

FIGURE 3. Finite Element Analysis of Top Plate

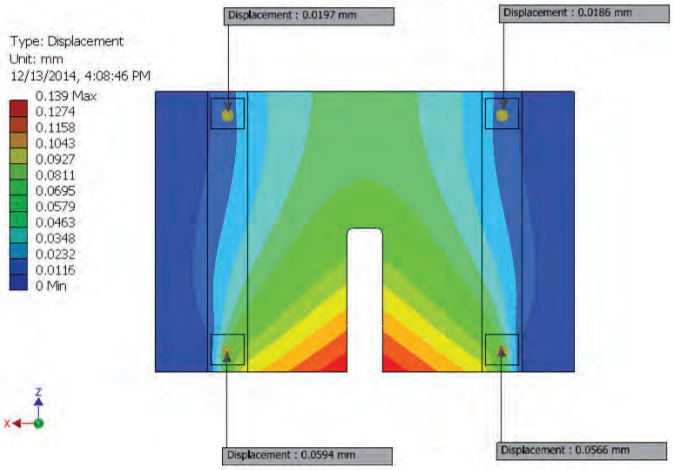

FIGURE 4. Finite Element Analysis of Second Plate

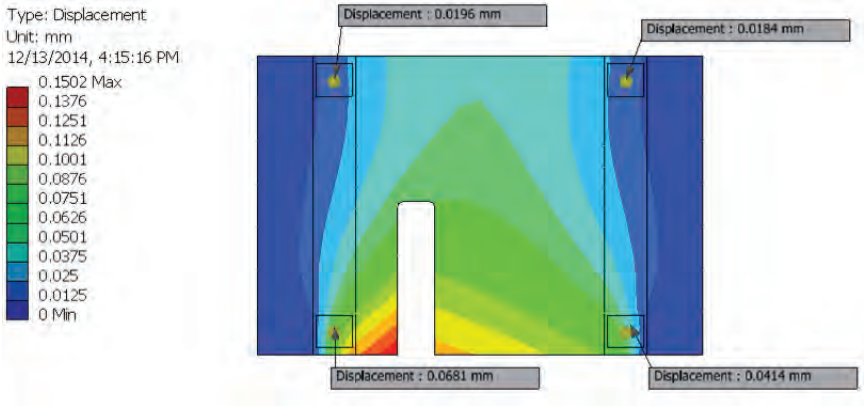

FIGURE 5. Finite Element Analysis of Third Plate

Discussion of Data

The 3-axis optical platform was completed and tested. The Keyence high accuracy optical micrometer was used to measure positioning of the table over 6 passes while the table was under loading. This test, results shown in Figure 6, included 3 passes in both the positive and negative direction (i.e. upwards and downwards). The root mean square error of the system after traveling in only one direction was 1.3 microns whereas that of the system after traveling one pass in each direction was 3.7 microns. This error was sufficiently small that the table was well within normal operating limits and determined to be fully functional. The shortness of the table also fulfilled the low profile requirements of the SOLARIS lab, and the table was tested under the desired loading requirements to ensure reliability of the platform. Photos of the Assembled 3-axis platform under zero load and under 1500 Kg load, are shown in Figures 7 and 8.

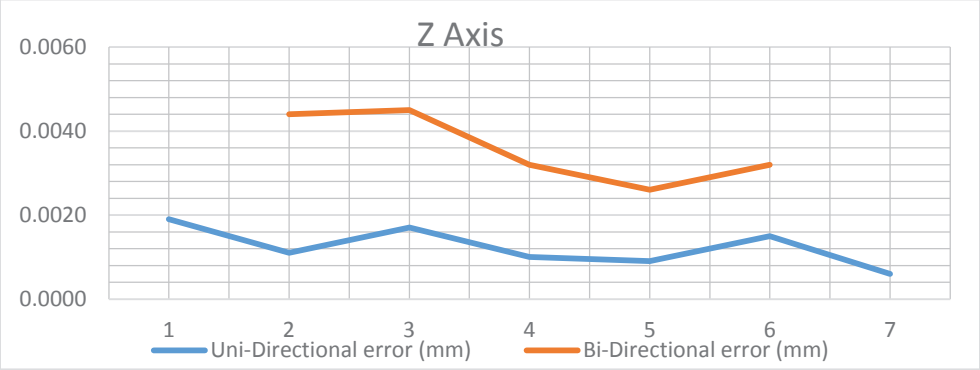

FIGURE 6. Position error of 3-axis platform in vertical axis

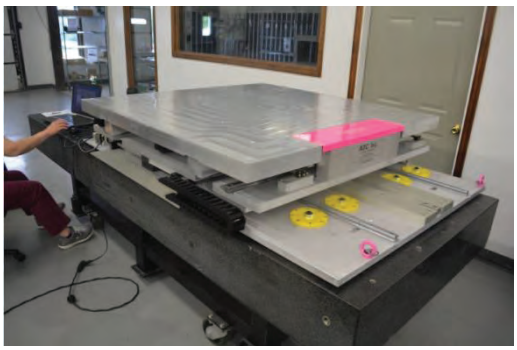

FIGURE 7. Photograph of the assembled 3-axis platform under zero load

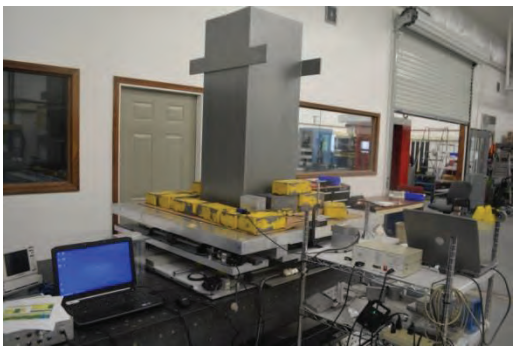

FIGURE 8. Photograph of the assembled 3-axis platform under 1500 Kg load

CONCLUSIONS

This design proved to be very reliable and meet the project requirements bot for low profile and high load as well as reputability.

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