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Development of Ultra-Small-Angle Neutron Scattering (USANS) Monochromator

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Abstract

In this paper ADC will discuss the design and test results for a mutil-axis positioning system for an ultra-small-angle neutron scattering (or USANS) method which is used for studying structure in the 100nm to 10μm range by diffraction. USANS uses a neutron beam with an extremely sharp angular profile which can be obtained by diffraction from a perfect crystal ("Bonse-Hart" technique). USANS instrument is basically composed of; Premonochromator (Si), Channel-cut monochromator crystal (Si), Channel-cut analyser crystal (Si), Neutron guide. In Australia. A number of similar instruments are in operation and are being used successfully including Laboratoire Léon Brillouin [1] and Hahn-Meitner Institute [2].

Introduction

This project covers a multi-axis positioning system for an ultra-small angle neutron scattering (or USANS) method is used for studying structure in the 100nm to 10μm range by diffraction. The complete system can be seen in Figure 1 below. For this application, a mix of ADC's standard products as well as new customized stages, were used.

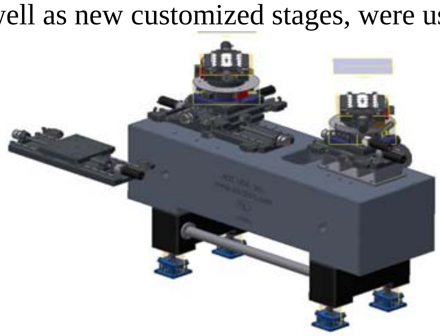

Figure 1: ADC's Modeled Design.

The main mechanical components consist of Two Tilt Stages: Non-magnetic materials employed, Range from stepper motor/encoder/mechanical interface: ± 3°, Resolution from stepper motor/encoder/mechanical interface: 0.0001μ, Repeatability: 0.00005μ, Absolute Accuracy: 0.001 μ; Three Rotation Stages: Non-magnetic materials employed, Range: 360°, Resolution from stepper motor/encoder/mechanical interface: 0.00005 μ, Repeatability from stepper motor/encoder/mechanical interface: 0.000025μ , Absolute Accuracy: 0.0005μ; Four X Translations: Non-magnetic materials employed, Net travel range: 120 mm, 200mm, 400mm, and 350 mm, Resolution from stepper motor/encoder/mechanical interface: 0.05 mm, Repeatability from stepper motor/encoder/mechanical interface: 0.05 mm, Absolute Accuracy: 0.1 mm; Two Monochromator YZ Slit System: Opening: 0-70 mm, Resolution: 0.01 mm , Repeatability: 0.01 mm , Absolute Accuracy: 0.05 mm, Slit blade material: Sintered B4C of 3 mm thickness; Multiple-position sample holder :100 mm (X), 400 mm (Y), weight < 20 kg.

Design

Premonochromator

For the placement of the premonochromator, seen in Figure 2, a rotation and tilt stage was used. For placement of channel cut monochromator crystal (CC1) positioning; a linear stage for the x axis, rotation stage was used around the z axis, and tilt stage was used in respect to the x and y axis'. For the channel-cut analyzer crystal (CC2) position; two linear stages were used in respect to the x and y axis'. A 500mm linear stage was used along the x axis for positioning the main detector. Also included with this system, were two slit systems for focusing the neutron beam.

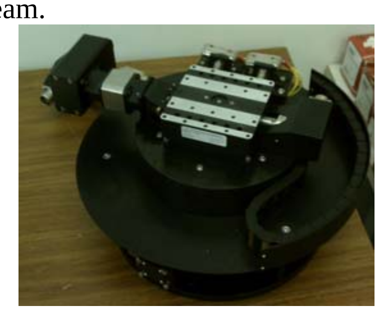

Figure 2: Premonochromator.

The tilt stage is a radiation resistant TS-160. The TS-160, seen in Figure 3 below, is equipped with a radiation hard motor/gearbox, radiation hard limit switches, kapton wiring, and a resolver for position measurement.

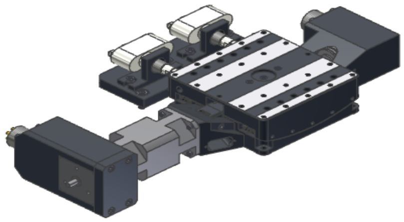

Figure 3: ADCs TS-160, radiation resistant.

This tilt stage has been designed for a resolution of 0.00005 degrees, an accuracy of 0.001 degree, and the ability to carry a load of 45 kg; test results can be seen in Figure 4 below.

ADC Design Test Results	
Mounting Surface	110 mm x 110 mm
Range	± 10°
Resolution	0.00005°
Repeatability	0.0001°
Absolute Accuracy	0.001°
Radiation Hardness	yes
Vacuum Rating	not required
Non-Magnetic Material	yes

Figure 4: ADC TS-160 design test results.

The rotation stage is a radiation resistant RS-200. The rotation stage, seen in Figure 5 below, is equipped with a radiation hard motor/gearbox, radiation hard limit switches, kapton wiring, and a 23 bit encoder encased in lead shielding.

Figure 5: ADC's RS-200, radiation resistant.

The rotation stage has been designed for a resolution of 0.0001 degree, and accuracy of 0.001 degree, and the ability to carry a load of 200 kg; test results can be seen in Figure 6 below.

ADC Design Test Results	
Mounting Surface	⌀ = 210 mm
Range	± 100°
Resolution	0.0001°
Repeatability	0.001°
Absolute Accuracy	0.01°
Radiation Hardness	yes
Vacuum Rating	not required
Non-Magnetic Material	yes

Figure 6: ADC RS-200 design test results.

Monochromator & Analyzer Stages

The total CC1 and CC2 positioning system can be seen in Figure 7, below.

Figure 7: CC1 & CC2 positioning system.

The tilt stage is a TSW-300. The TSW-300, seen in Figure 8 to the right, is equipped with a high precision motor/gearbox, highly durable limit switches, and a 17bit multi-turn encoder for position measurement.

Figure 8: ADC's TSW-300

This tilt stage has been designed for a resolution of 0.0001 degrees, an accuracy of 0.00005 degrees, and the ability to carry a load of 45 kg; the test results can be seen in Figure 9 below.

ADC Design Test Results	
Mounting Surface	225 mm x 230 mm (interface plate)
Range	± 8°
Resolution	0.0001°
Repeatability	0.00005°
Absolute Accuracy	0.001°
Radiation Hardness	not required
Vacuum Rating	not required
Non-Magnetic Material	yes

Figure 9: ADC TSW-300 design results.

The rotation stage is an RS-200. The RS-200 rotation stage, seen in Figure 10 below, is equipped with high precision motor/gearbox, highly durable limit switches, and a 23 bit encoder.

Figure 10: ADC's RS-200

This rotation stage has been designed for a resolution of 0.00005 degrees, an accuracy of 0.0005 degrees, and the ability to carry a load of 200 kg; test results can be seen in Figure 11 below.

ADC Design Test Results	
Mounting Surface	∅ = 210 mm
Range	±100°
Resolution	0.00005°
Repeatability	0.000025°
Absolute Accuracy	0.0005°
Radiation Hardness	not required
Vacuum Rating	not required
Non-Magnetic Material	yes

Figure 11: ADC RS-200 design results.

Linear Stages

For this project, ADC used a total of four linear stages; 1X150mm, 1X250mm & 2X500mm. The pair of 500mm stages can be seen in Figure 12 below. Each linear translation stage is also equipped with high precision motor/gearbox, highly durable limit switches, along with a 17 bit multi-turn encoder.

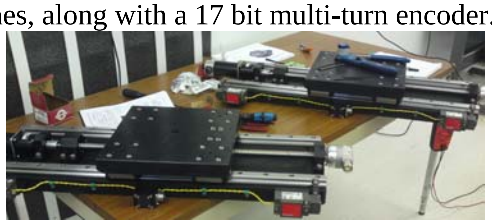

Figure 12: ADC's Linear Stages, 500mm.

The linear stages have a designed resolution of 0.001 mm, an accuracy of 0.01 mm, and the ability to carry 500kg; test results can be seen in Figure 13 below.

ADC Design Test Results	
Range	150mm/225 mm/500mm
Resolution	0.001 mm
Repeatability	0.002 mm
Absolute Accuracy	0.01 mm
Radiation Hardness	not required
Vacuum Rating	not required
Non-Magnetic Material	yes

Figure 13: ADC Linear stages design results.

Customizable Slit System

Each axis in this slit is independent of one another, so this slit is fully scan able within its limits. This slit is equipped with high precision motors/gearboxes, limit switches, along with 13 bit multi-turn encoders. The custom system can be seen below in Figure 14.

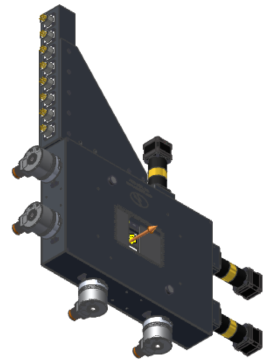

Figure 14: Customizable slit system.

The designed resolution is 0.0003 mm, and an accuracy of 0.005 mm; design test results can be seen in Figure 15 below, as well as a photo of testing being done on the system in Figure 16 to the right.

ANSTO Design Requirements	
Option	Motorized
Range	0-70 mm/0-115mm
Resolution	0.0003 mm
Repeatability	0.001 mm
Absolute Accuracy	0.005 mm
Radiation Hardness	not required
Vacuum Rating	not required
Non-Magnetic Material	yes
Slit Blade Material	Sintered B_4C of 3 mm thickness

Figure 15: Customizable slit system design results.

Figure 16: Slit system linear positioning testing.

References

[1] S. Désert, V. Thévenot, J. Oberdisse and A. Brûlet (2007). Journal of Applied Crystallography

[2] M. Strobl, W. Treimer, C. Ritzoulis, A. G. Wagh, S. Abbas and I. Manke (2007). Journal of Applied Crystallography