MILLIPROBE SCANNER STATION*

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Abstract

The research team at the Commonwealth Scientific and Industrial Research Organisation, Clayton (CSIRO) have developed a the high energy dispersive detector referred to as the Maia. The rapid scanning, high resolution detector offers technological advances, including non-invasive technical study of highly valued artwork.

A vital application of the maia detector is scanning x-ray fluorescence microscopy for obtaining the elemental composition of a large number of materials.
The innovative detector allows connection between scientists and arts communities to increase their understanding of historical artworks, broadening the field of authentication and potentially aiding the fight against art forgery as well as historical information.

We have designed a new dedicated milliprobe station that offers improvements in stability, motion control and mounting. The structure is designed to support and scan various samples in size as well as shape powered by X and Y stages. A slide and hold clamping concept has been implemented, incorporating carbon fiber tubes, which provides easy and rapid assembling of samples. This arrangement provides excellent interchangeability, supporting a variety of planar and non-planar samples for scanning [1].

INTRODUCTION

For several years we have used a prototype 'milliprobe' apparatus to successfully scan large objects. Examples include paintings from the National Gallery of Victoria, historical photos and a Melbourne Cup – Australia's most prestigious thoroughbred horse race trophy.

MAIA DETECTOR

Thanks to the highly sensitive CSIRO and Brookhaven National Laboratory (BNL) developed maia detector. The maia system is a high-throughput x-ray fluorescence detector and real-time analysis system that allows samples to be scanned up to 1000 times faster and in much greater detail than previous methods.

When combined with a focused x-ray source, such as the x-ray fluorescence microprobe beamline, it is able to produce high-definition, quantitative element images with microscopic detail in real-time [2].

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TECHNICAL SPECIFICATIONS

Ability to adjust beam addressable sample area: X axis: 600 mm, Y axis: 1200 mm travel.
X Stage: Parker 404XR, Motor Sanyo Denki Stepper 56 mm 103H7128.
Y stage: Parker 406XR, Motor Sanyo Denki Stepper 56 mm 103H7128.
Scanning Speed of X stage & Y stage: 20 mm per second.
Maximum sample size: 1250mm Height x 1750 mm wide x 50 mm thick.
Minimum sample size: 100 mm high x 100 mm wide.
Maia Detector minimum scanning distance: 2 mm from sample plane.
Maximum weight of sample: 15 kg.
Weight of structural stand: 276 kg.
Total Assembly Weight: 420 kg

CONCEPTUAL DESIGN

The design envelope included beam addressable regions to cover 1200 mm by 600 mm for large samples limited only by hutch wall constraints. We proposed several conceptual designs to achieve the specifications generated by our scientists, which were finalized during our design review.

The clamps are secured using knobs where feasible, providing quick release concept, reducing the number of tools required during installation and dismantling of sample. High stability and precision was an essential part of the design criteria. Early structural support of small artwork consisted of aluminium extrusions clamped together to help provide the requirements of this size. As the demand grew for larger format artwork, we introduced a large square tubular frame. This reinforced rigidity of the platform assemblies especially during transit mode.

Vertical carbon fiber tubing can also be disassembled to cater for a combination of smaller size samples reducing any vertical congestion within the surroundings of the hutch. The slots in the vertical side clamps are employed to fine tune any vertical misalignment of the artwork during installation.
Wide linear rails/carriages cater for ease of moment loading, increasing rigidity during motion of the upper and lower platforms. The implementation of counter weights on each side provides reduction of motor load on the vertical stage during transit. The design includes standardisation on same size fasteners to ease the assembly procedure and the number of tools required.

PROTOTYPE CONSTRUCTION

Due to highly interactive and frequently used platforms, we printed 3D prototypes in house using abs plus generated accuracy in line with traditional manufacturing. The construction help prove form, fit, functionality of railing and platforms, confirming the feel, touch, space utilisation & sequence of sample assembly prior to releasing components for manufacture.

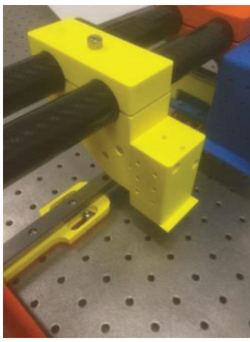
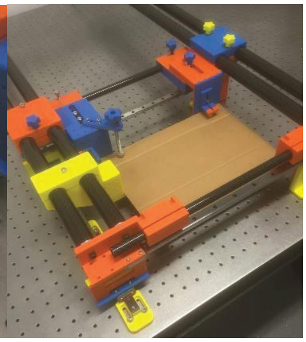

Figure 1: Side clamp assembly. Figure 2: Upper & lower platforms.

The side clamp assembly offers tuning in squareness (horizontal alignment) within a tolerance of ± 20mm of the artwork frame and the option of interchangeable clamps for the support of cylindrical samples. (see Fig.1)
The Upper & lower platform assemblies consisted of linking carbon fiber tubing, which help assess the rigidity of structure (see Fig. 2).

TESTING

Using the roll wrap carbon fiber tube provided excellent strength, withstanding twist, torque, compression, tension and deflection without splitting. This is due to the fibers been wound around the diameter of the tube as well as running in length direction.

The tube mandrel is wound with unidirectional carbon fiber around the diameter, and then wrapped with fibers along the length (longitudinally). It is completed with a wrap of 3k twill before it is cured in an autoclave, roll sanded then recoated with epoxy. The assessment below was paramount to our design, clarifying twisting of the horizontal stage in its maximum stroke, securing the complete surface area to the breadboard table.

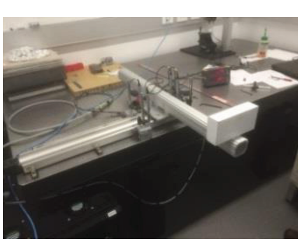
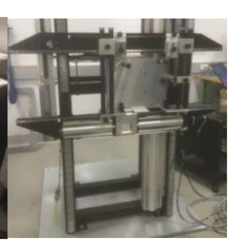

Figure 3: X stage assessment. Figure 4: Small artwork installation.

The X stage extrusion assembly was secured to the breadboard table. Using a 9 kg lead brick at a span of 600 mm, we simulated the equivalent moment in a cantilevered scenario based on our prototype concept which resulted in 0.86 mm in deflection on the stage (see Fig.3).

We simulated the installation of small artwork onto the upper and lower platforms. When assessing the technique, we conducted a work hazard risk analysis with our safety team and independent personnel. (See Fig.4)

MOTION CONTROL

As experienced with the prototype ‘milliprobe’ stage, the fast scanning axis can introduce vibrations through the linear stage to the large sample frame. We did testing to overcome this problem and plan to switch to a servo motor drive system for smoother scanning.
In the new design, a stepper motor moves the [vertical] scan axis whilst the other stepper motor moves the [horizontal] raster axis. A GeoBrickLV® provides tuning and trajectory planning capabilities required to achieve high trajectory tracking performance scan motion.

MANUFACTURING

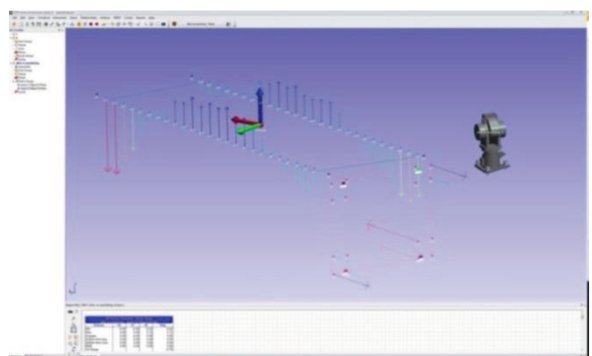

Figure 5: Tubular frame laser scanning.

The test indicated a 0.36 mm variation from right hand bottom to top left hand regions of the frame (Tubular Frame structure orientation: seated in horizontal plane for testing purposes only using a laser tracker) (see Fig. 5).

CONCLUSION

The structure has recently being installed in the x-ray fluorescence microscopy end station (see Fig. 6). It is intented to raster scan at several points to assess the deflection of the assembly at different positions of the moving frame in the
x and y planes. We wish to achieve a result under 100 micron variation from the plane.

In the interim, we assembled the station in our machine assembly room to confirm form, fit & function prior to commissioning. This included assessing the operation of counterbalance weights linked with the lower platform and moving both platforms in the upper & lower positions along the wide rails & bearings. Ultimately confirming parallelism of the linear tracks, with the rigidity of the carbon fiber tubing assembly being paramount.

Figure 6: Milliprobe scanner station recently installed in XFM end station.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Scientific Reports 6, Article number: 29594, A Hidden Portrait by Edgar Degas. David Thurrowgood1, David Paterson, Martin D. de Jonge, Robin Kirkham, Saul Thurrowgood & Daryl L Howard, December 2015. http://www.nature.com/articles/srep29594

[2] CSIRO Research Minerals Mineral discovery and exploration Resource characterisation Our Research: Maia x-ray imaging: finding hidden 'needles in a haystack' http://www.csiro.au/en/Research/MRF/Areas/Mineral-exploration-and-discovery/Rapid-resource-characterisation/Maia.