

THE INTERACTION BETWEEN SAFETY INTERLOCK AND MOTION CONTROL SYSTEMS ON THE DINGO RADIOGRAPHY INSTRUMENT AT THE OPAL RESEARCH REACTOR

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Abstract

A neutron radiography/tomography instrument (DINGO) has been commissioned at the Bragg Institute, ANSTO. It utilises thermal neutrons from HB2 of the OPAL research reactor with expected flux up to 4.7×10^7 [n/cm²s] at the sample. One component of the instrument is a 2.5 tonne aperture selector wheel filled with a shielding mixture. It provides six openings which are equipped with various neutron beam optics plus a solid 'shutter' section to block the beam. Utilising the solid section as a shutter requires complex interaction between the safety interlock and motion control systems. A standardised Galil based motion system controls the movement of the wheel while a Pilz safety PLC specifies the desired position and handles other safety aspects of the instrument. A shielded absolute SSI encoder is employed to give high accuracy feedback on the position in conjunction with a number of limit switches. This paper details the challenges in creating a motion system with inherent safety, verifying the wheel meets specifications, commissioning and the considerations in selecting components to withstand high radiation environments.

INTRODUCTION

The DINGO Radiography instrument is the first at the Bragg Institute to use the HB2 thermal beam with an estimated flux of up to 4.7×10^7 [n/cm²s]. The main components of the instrument (heading outward from the reactor face) consist of a primary collimator, collimation wheel, Tertiary & Fast Shutter, sample stage, detector camera and beam stop (Figure 1). The collimation wheel is a single axis drum filled with a wax/steel shielding mixture and six square cut outs for neutron optics and a larger solid shielding sector to act as a shutter.

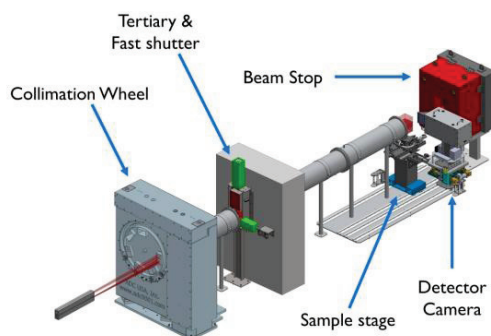


Figure 1: DINGO instrument layout.

All neutron scattering instruments at Bragg require an associated Primary, Secondary and Tertiary Shutter for safety reasons (some Primary/Secondary Shutters are shared). These shutters block the neutrons when closed making the instrument area safe to work in. The decision was taken to use the collimation wheel as a Secondary Shutter as well as providing collimation. This prevents the need for another shutter to be added and utilises a component that is already required thus taking up less space.

The challenge in using the collimation wheel for this dual purpose is historically the safety interlock and motion control systems have minimal interactions with each being electronically isolated from each other. The only standard interaction they have is that of the estop function; where a motion contactor is opened disabling all the drive motors.

The fact that the collimation wheel is in a high radiation area also requires consideration and is enclosed behind 500mm concrete shielding (Figure 2). Access to the area is by means of a crane and can take a substantial period of time to remove and replace. These reasons make the selection of components critical with attention being paid to robustness and radiation resistance as any failure can take a long time to correct.

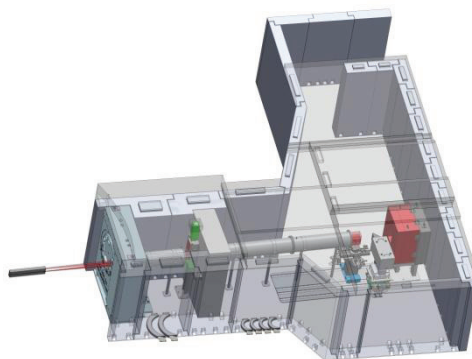


Figure 2: Instrument layout with concrete shielding.

SYSTEM DESIGN

Safety Interlock System (SIS)

The Primary Shutters at Bragg are not fail safe, not linked to the SIS and thus cannot be relied on to act as a safety device; however the Secondary and Tertiary Shutters are controlled by the SIS. A Pilz PSS3000 Safety programmable logic controller is the primary control device for the each SIS.

The Tertiary Shutter on DINGO is a combination of lead, B₄C and a borated polyethylene. It is attached to a pneumatic cylinder and drops under gravity to block the neutron beam. The position of the shutter is monitored via Haydon Kerk limit switches. These components are radiation resistant due to their use of ceramics and instead of polymer based materials. This system is Category 4 according to AS4024 Safety of Machinery.

The Secondary Shutters throughout Bragg have varying designs that include; pneumatic cylinders that fall under gravity, pneumatic cylinders that open downwards, pneumatic cylinders that open sideways and motor controlled. The Secondary Shutter on DINGO is motor controlled but with a much more complex system than other motor controlled shutters. This system is not Category 4 and is no greater than Category B so the challenge is making its operation safe and reliable.

Motion Control System

The collimation wheel is driven by 2 phase Empire Magnetics stepper motor controlled by a Galil based motion control system. A resolver would have been the preferred position measurement device because of the high radiation expected in the area however the requested resolution of 0.01° could not be achieved. The resolution with a resolver and 12 bit SSI conversion card was 0.0103° thus a Kübler 13 bit single turn SSI optical absolute encoder was chosen giving a resolution of 0.005°. It is covered by a lead shielding pot to reduce radiation it is exposed to. The encoder is geared to the slewing bearing with an anti-backlash gear to improve accuracy and reduce backlash.

Three Category 4 Euchner limit switches are utilised; each has 3 positively driven normally closed and 1 normally open contacts. Two are used to ensure the wheel does not rotate more than 360° and the third is used to indicate that the wheel is in a shutter blocked position.

A motion control contactor supplies power the motor amplifier. This contactor is separate to the contractor that supplies power to the rest of the motion controllers. It is controlled by the safety PLC so that it can be isolated if the logic dictates. A test pulsed input provides feedback on the status and health of the contactor.

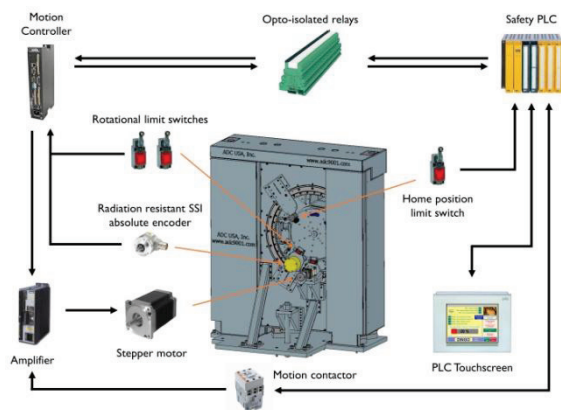


Figure 3: Collimation wheel block diagram.

The safety interlock and motional control systems are electronically isolated so any transfer of signals between the two is done by optically isolated relays. The transfer of data between the two is in discrete binary form which adds difficulty in the case where values such as shutter position and progress are to be transferred. A Pilz touchscreen provides the main interface to the system and allows the user to select which aperture they would like to use. Figure 3 shows a summary in block diagram form of the motion control and safety interlock interactions.

PROTOTYPING

For this project a model collimation wheel (Figure 4) was created for prototyping the interface and logic between motion and safety systems. A slewing bearing was sourced and driven by a motor and monitored by an encoder and limit switches to make a rudimental model collimator wheel. This proved valuable in working on the code before any of the actual components were built.

All safety interlock system software is prototyped on a bench top environment before being implemented in the field. A simulator using a test PLC and all associated field devices was constructed to do this work.

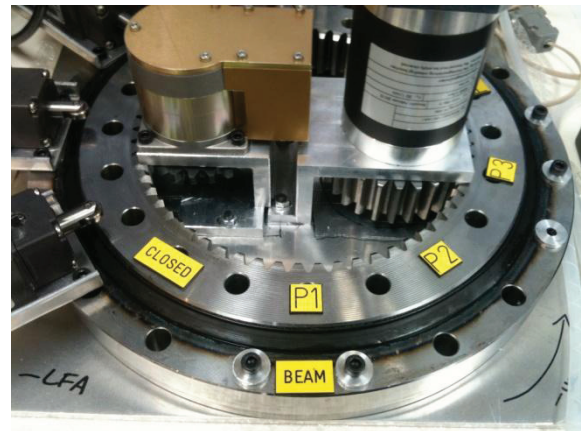


Figure 4: Prototyping collimation wheel.

RESULTS

Factory Acceptance Testing

The collimation wheel was designed and manufactured by an external engineering company, Advanced Design Consulting [1]. This meant that a thorough testing procedure was required to ensure the component met specifications. Open loop and closed loop positioning tests were completed at the manufacturers premise and the wheel was rotated more times than it is expected to in its lifetime. Tests were performed using an electronic tilt meter mounted to the face of the wheel to compare the actual position with the measured position. This method was used to check parameters such as accuracy and repeatability complied with specifications.

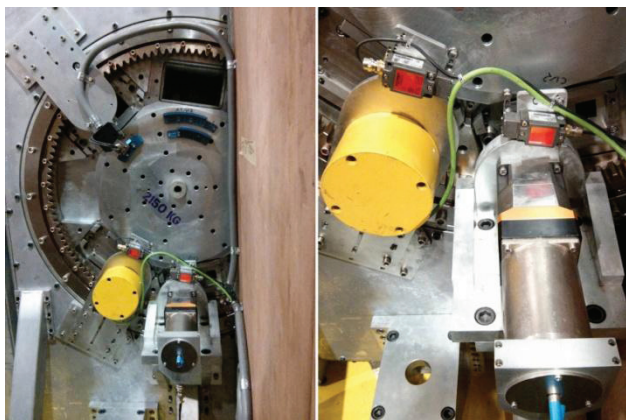


Figure 5: Installed collimation wheel.

Interface

The SIS interfaces for each instrument at Bragg are fairly generic with only slight variations depending on what components the instrument has. Figure 6 shows the touchscreen design that was created for DINGO.

The speed of the collimation wheel was not a concern for the user with requirements for a full rotation being around 20 minutes. Though because of this slow speed the user requested some feedback on how the progress of the wheel and some indication of whether the wheel had failed at any stage. A progress indicator bar was added to the touchscreen as percentage of the move completed. This involved using the encoder value to calculate the initial and final values and constantly update the value. This logic is done by the Galil motion controller and sent to the safety interlock system as binary grey code using relays to keep the two cabinets isolated.

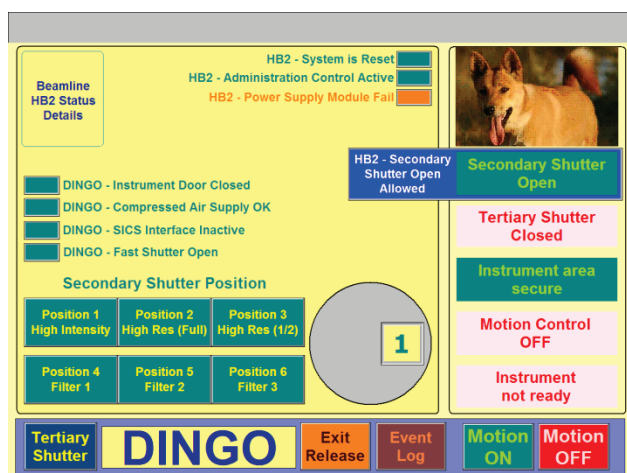


Figure 6: DINGO touchscreen interface.

Commissioning

Commissioning a SIS at Bragg has a standard procedure for all instruments and is required by the nuclear regulator before an instrument can get a hot commissioning license. A document for each system is

written and specifies the tests that are required to be carried out and all likely failure modes are performed and checked against expected response. This is done with the Primary Shutter locked closed and tagged out in case the tests do not go as expected.

CONCLUSION

The DINGO instrument was commissioned during 2013 and took its first neutron radiography image during August of a mechanical alarm clock (Figure 7). Time will tell how robust and reliable the design of the Secondary Shutter system is but a number of design considerations have put it in good stead.

One problem that has already come across is that if the encoder fails it will output an error code SSI value and the wheel will try to drive to this value which is outside the range. One way to combat this is to add a condition that checks if the encoder is reading that error code and reports an error.

The extent of prototyping and testing during this project has been valuable with very few errors needing rectification during final implementation. The investment in prototyping during the early stages has saved a lot of time and money in the implementation phase.

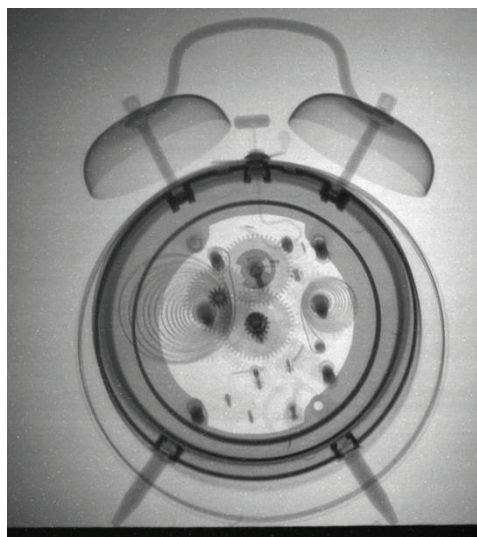


Figure 7: First image from DINGO.

ACKNOWLEDGMENTS

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REFERENCES

- [1] Advanced Design Consulting,
<http://www.adc9001.com/products/view/462>.