Background

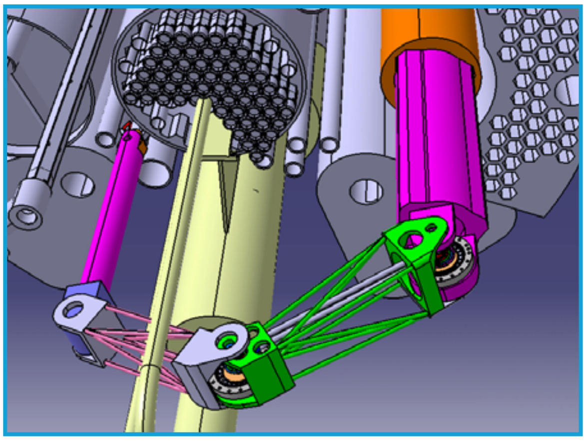
The experimental Accelerator Driven System XT-ADS is being developed within the European 6th framework programme EUROTRANS using the MYRRHA DRAFT-2 as starting point. The aim for the XT-ADS is to demonstrate the feasibility of the ADS concept at reasonable power levels and to serve as a high performance, multi-purpose experimental irradiation device. One of the fundamental design options that has been taken is to do all maintenance and in-service inspection and repair (ISIR) duties by remote handling. Outside the XT-ADS vessel in a controlled though radio-active environment, remote handling concepts as those already in use at e.g. the Joint European Torus (JET) can be used. Extrapolation to remote handling inside the lead-bismuth eutectic (LBE) filled main vessel of the XT-ADS is in principle feasible as was shown in a 2003 study performed by Oxford Technologies ltd for the case of MYRRHA. Nevertheless, it is clear that all critical remote handling components need to be qualified for use in liquid LBE. Thus, as a first step, a proof of principle (POP) experimental test rig is required.

Objectives

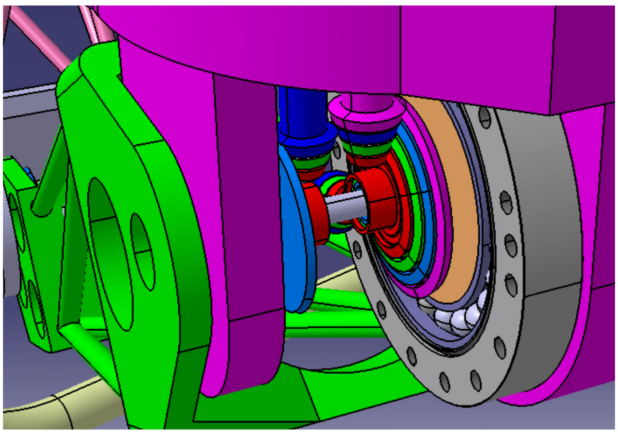
The principal goal of this work is to identify the critical technological issues that must be resolved to allow operation of remote handling manipulators inside the LBE filled main vessel of the XT-ADS and to propose a concept design and specification catalogue for a proof of principle test rig that is able to experimentally verify the main aspects of manipulator design.

Principal results

At the start of the study existing concepts for the ISIR approach for the XT-ADS, i.e. the In-Vessel Periscope Manipulator (IVPM), In-Vessel Inspection Manipulator (IVIM) and In-Vessel Recovery Manipulator (IVRM) were reviewed to provide a baseline for the design of the POP test rig. Also the kinematic range and dynamic load of each manipulator were calculated. For the development of the POP test rig it is important to keep the general manipulator design in mind. Clearly the manipulators must operate in the LBE at temperatures up to 350°C. No prime movers or sensors except for the ultrasonic (US) camera will be below the LBE. Proper management of the US camera cable and sufficient stiffness and load bearing capacity of gears and bearings must be foreseen. Finally, means of recovery from failure must be provided.



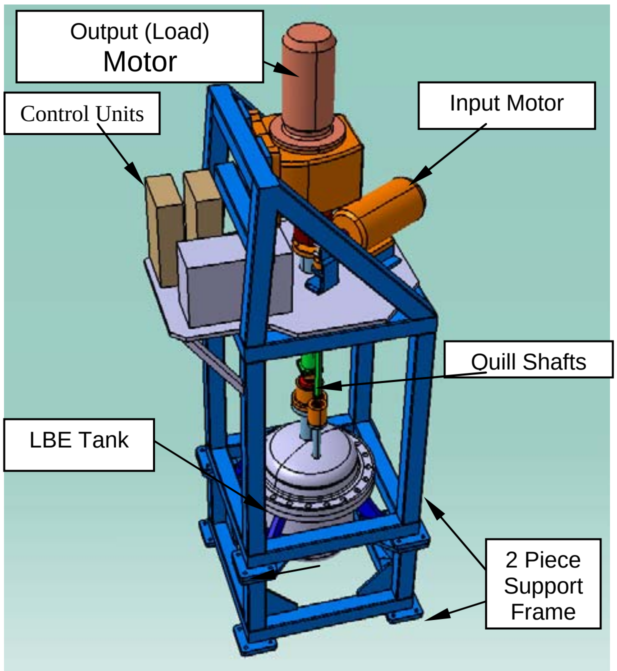
The IVRM being deployed in the main vessel



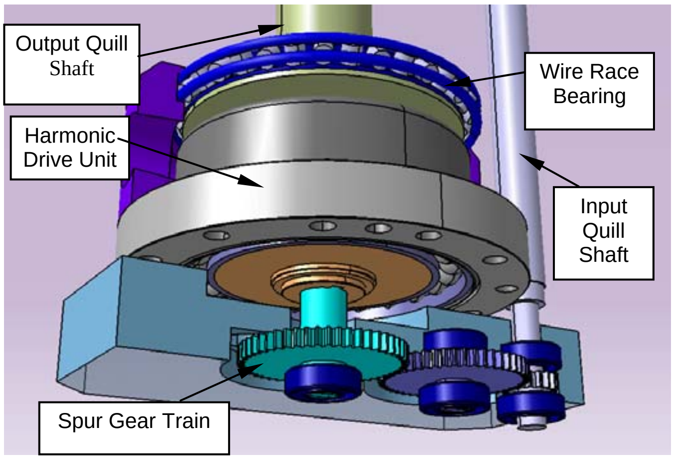
Detail of the first joint with nested bevel gears

To set up the test, the basic transmission and bearing technologies that are employed in the robotic arms and joints as well as the materials used in the construction are identified. These include:

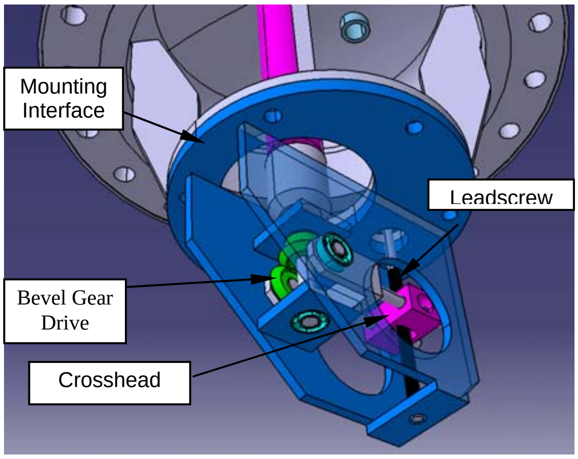
- Levers and pushrods that provide a simple stiff drive with limited angular range,
- Involute spur gears and bevel gears for stiff mechanical linkage of the actuation. Here spur gears will be tested as "wear" representation of involute bevel gears.
- Harmonic drives that act as compact reduction gearboxes providing a large single stage velocity ratio and joint stiffness free of backlash. A sizeable drive will be tested at maximum load factor.
- Leadscrew and linkage used in a gripper that transforms a rotary drive to a linear opposed clamping motion. The test in this case will be performed on a screw and pin jointed linkage system.
- Wire race roller bearings using coated carbon steal wires and ceramic or coated carbon steel rollers.
- Single row ball bearings from stainless steel with lubricating coating (WS_2)
- Ceramic bush bearings employing Syalon 050 ceramic without lubricants.
- Electric cabling elements with a ϕ1mm mineral insulated wire arranged in a 60 mm loop that is reduced to 40 mm in motion. The cabling is needed for the transmission of the US camera signals.



With the list of components to be tested in mind the POP test rig was designed. Its purpose is to determine the performance of the selected components in LBE under cyclic operation under a representative load. For that purpose key parameters are measured and recorded and derived parameters are calculated. Eventually, the test results should generate an optimised design of the in-vessel manipulators. The test rig consists of a LBE container vessel in which a total of four different test set-ups can be installed performing the experiments mentioned above. These are: the bearing module testing the operation of ball and plain bearings under radial loading conditions; the joint actuator module testing torsional loading of typical joint actuator drive components including gears, harmonic drive, and wire race bearings; the gripper module testing the leadscrew and linkage mechanism required for the IVRM gripper and finally the cable test set-up testing bending flexure of the cable of the ultrasonic camera. On top of the vessel, an input motor, a load motor and control units are installed. The parameters that are measured are the torque input and output, the positional offset of input and output, the rotation speed, the input and output angular range, the LBE temperature and the number of cycles. By combining different measured parameters, component properties like power input, power output, efficiency, joint stiffness, backlash and wear can be determined. The first step in the test programme is to test the module at 350ºC in air or argon. This will establish the backlash and efficiency of the assembly as the benchmark performance. Then experiments in the LBE environment will take place. Each module is to be cyclically exercised under a representative load over its full angular range. After a failure or the completion of the required cyclic test, the test module will be dismantled, cleaned and inspected - this analysis will be correlated with the data logged during the test.



Joint actuator test module



Gripper test module

Future work

After the design of the POP test rig the obvious next step is the construction of the device and the performance of the proof of principle tests for the different manipulator components. This work is planned for the period 2007-2008.

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Main reference

Paul Schuurmans, Simon Mills, Darren Locke, Richard Meek "ISI & R remote handling proof of principle : phase 1 final report and design of test rig for phase 2" Deliverable 4.17 of the 6th framework programme of the Euorpean commission IP EUROTRANS, November 2006