Development of In-cell crane for use in lead cell

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HOTLAB 2019, India  09/09/2019
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Introduction

- Radio Metallurgy Laboratory (RML) at IGCAR, Kalpakkam consists of seven concrete hot cells & one lead cell for Post Irradiation Examination (PIE) of irradiated materials.

- These cells are α-β-γ type

- Activities related to commissioning of lead cell is progressing

- A newly developed 50kgf capacity in-cell crane has been installed inside the lead cell containment box for shifting of in-cell equipment
Description of the lead cell

- The Containment Box (CB) of lead cell is made of stainless steel (AISI 304L)
- CB is mounted on support structure at an elevation of 1m.
- Shielded cubical is provided around the CB.
- Lead shielding of 250mm thickness is provided in east, west & south sides
- Concrete shielding of 1.2m thickness is provided in the north side
- Top of lead cell is shielded by mild steel of 300mm thickness
Dimensions of the lead cell

- Outer dimension of lead cell: 6m X 1.6m X 3m (L X B X H)
- Inner dimension of Containment Box (CB): 5.2m X 1.2m X 1.4m (L X B X H)
- CB rear wall opening size: 630mm(B) X 830mm(H)
- CB floor opening size: Ø 360mm
- MSM port opening size: Ø 170mm
Features of the lead cell

- Radiation shielding window : 4nos (on the lead wall)
- Lighting window : 4nos (in the roof of CB)
- Articulated Manipulator (AM) : 8nos. (two nos. each above Radiation Shielding Window)
- Inter cell transfer port between hot cell#7 and lead cell containment box
- Three glove boxes are linked with CB for material transfer
Need of the crane inside the RML lead cell

- Originally the lead cell was designed for fixed layout of equipments inside the containment box.

- Addition of new equipments/ replacement of equipments were not envisaged

- Manipulator of 4.5kgf capacity is used for remote material handling inside the lead cell.

- Manipulators capacity is not sufficient for the handling of PIE & specimen preparation equipments

- To improve operational flexibility, it is decided to add a 50kgf capacity in-cell crane
## Important design considerations for crane

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Design considerations</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight of crane should be as low as possible</td>
<td>wall thickness of CB is 3mm</td>
</tr>
<tr>
<td>2</td>
<td>Restrictions in the sizes of crane components</td>
<td>Construction of the lead cell is already completed, hence the available openings have to be used for crane installation</td>
</tr>
<tr>
<td>3</td>
<td>The design should be compact</td>
<td>To minimize the usage of expensive lead cell space</td>
</tr>
<tr>
<td>4</td>
<td>Easy to assemble</td>
<td>Lack of material handling devices in the lead cell and confined space</td>
</tr>
<tr>
<td>5</td>
<td>Long life for equipment &amp; components</td>
<td>remote repair is difficult</td>
</tr>
<tr>
<td>6</td>
<td>Materials should be radiation damage resistance</td>
<td>lead cell is designed to handle 37000GBq (1MeV γ-ray)</td>
</tr>
<tr>
<td>7</td>
<td>The crane should be amenable for remote operation by manipulators</td>
<td>No other remote handling device</td>
</tr>
</tbody>
</table>
Brainstorming to develop the lead cell crane

- Discussions were conducted to design the crane, conclusions are given below

**For Long Travel (LT) stage**

**Chain drive**: Not selected due to multiple links, need of lubrication and sagging

**Rope drive**: Not selected due to possibility of slip and sagging

**Lead screw drive**: Selected due to positive drive, self locking, minimum lubrication requirement and more reliable

**Input power to LT mechanism**: Motor & manual (Motor should be placed in a location accessible by manipulator)

- Similarly for Cross Travel (CT) lead screw was selected

- For Hoist spline shaft, rope & single grooved drum was selected

- Input power to CT & hoist: Manual (due to short travel)
Description of the in-cell crane (1/2)

An in-cell crane consisting of long travel stage, cross travel stage and hoist has been developed and installed inside the lead cell containment box for lifting and shifting of materials & equipments

Lifting capacity of crane: 50kgf

2D view of the crane inside the containment box
Description of the in-cell crane (2/2)

Motions:
- Long Travel (LT) motion – 3.96m
- Cross Travel (CT) motion – 0.6m
- Hoist motion – 1.15m

Overall dimensions of the crane
- 4.65m (L) X 1.18m (B) X 1.02m (H)

Purpose of the in-cell crane:
- Shifting of in-cell equipments
  - To install new equipments
  - Replacement of irreparable equipments
- Efficient utilization of lead cell floor space
- To improve the operational flexibility
3D model of the crane

- Hollow lead screw
- LT stage
- Handle
- CT & Hoist assembly
- Stepper motor

Enlarged view of handle and motor
Components of long travel motion:

- Hollow lead screw – (OD: 100mm, ID: 86mm, L: 4200mm)
- Partial floating nut (ACME 100 thread)
- Channels for guide the trolley – (140mm X 60mm X 4400mm)
- Trolley – (590mm X 400mm X 170mm)
- Stepper motor
- Spur gears
- Bevel gears
Cross travel stage & hoist components

- Lead screw— (Ø20mm, L: 875mm)
- Linear guide shaft and bush (Ø 20mm, L: 815mm)
- Spline shaft and nut— (Ø 20mm, L: 900mm)
- CT Trolley— (245mm X 120mm X 145mm)
- Rope drum, rope, hook
- Worm & worm wheel
- Bevel gears
- Major components of the crane were fabricated using Stainless steel.
- The drive motor used was tested for radiation resistance up to $10^8$ rads of 1MeV $\gamma$-rays.
- Crane performance testing was conducted results are given in next slide.
## Test results

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Description</th>
<th>Specified value</th>
<th>Measured value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Long travel length</td>
<td>3960mm</td>
<td>3963mm</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cross travel length</td>
<td>600mm</td>
<td>601mm</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Lifting height</td>
<td>1150mm</td>
<td>1165mm</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Time taken to complete the long travel motion (motor)</td>
<td>10 min. to 15min.</td>
<td>13min.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Applied torque for long travel (manual)</td>
<td>≤ 3Nm</td>
<td>0.4Nm</td>
<td>At 100% SWL</td>
</tr>
<tr>
<td>6</td>
<td>Applied torque for cross travel</td>
<td>≤ 3Nm</td>
<td>0.4Nm</td>
<td>At 100% SWL</td>
</tr>
<tr>
<td>7</td>
<td>Applied torque for hoist</td>
<td>≤ 3Nm</td>
<td>2.9Nm</td>
<td>At 100% SWL</td>
</tr>
<tr>
<td>8</td>
<td>Deflection value of the hollow screw shaft due to self weight</td>
<td>≤ 2.5mm</td>
<td>2.0mm</td>
<td>At no load and 100% SWL</td>
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Erection of the crane

- All glass windows were protected
- To avoid damages in the CB floor, it was covered by rubber sheet
- Special lifting jacks were placed inside the CB
- Crane components were shifted inside the CB and placed on the lifting jacks
- Assembly of crane inside the lead cell was completed
- The crane was lifted to position and it was fixed with CB
Summary

- An in-cell crane has been developed and installed inside a completely built lead cell. Since crane components have to be taken inside the restricted openings of the containment box, there were severe constraints in the design of crane components. **Solution:** Innovative design methodologies were adapted to overcome the constraints (e.g., partial floating nut).

- The crane uses a remotely replaceable motor provided inside the lead cell for the operation of the LT stage. No drive shaft penetration through the CB wall and no attached glove box for motor replacement.

- The whole exercise gave good experience to the designers in the development of a material handling equipment suitable for remote operation and its installation in confined space.