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Facilities for the next century - Fabrication of CT specimens with inserts of irradiated material by milling and EB-welding

Presentation at the EWG "Hot Laboratories and Remote Handling - 2000 at PSI, CH"

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Summary

The operational age of nuclear power plants is increasing. Nuclear power plant life extension studies are done to assure safe operation of the plants. In such studies further controlled mechanical testing of irradiated materials, i.e for crack propagation studies are needed. A consideration hereby is to do as much testing on as little material as possible. With this in mind the HBWR project specially designed miniature samples such as CTs with irradiated inserts in the crack growth region, fabricated suitable test samples and performed tests simulating BWR and PWR conditions, successfully.
A capability of machining samples from irradiated steels was needed. In the last years the Hot Lab at the Institute for Energy Technology at Kjeller, Norway has enlarged its remote handled machining capabilities with installing of a remote handled milling unit.

In this presentation a description of the milling facility in the hot cell is given. The remote handled milling machine and EB-welding is used in the fabrication of compact tension specimens (CTs) with irradiated steel inserts in non-irradiated steel CT bodies.The irradiated inserts, either disc or square shaped, are located in the crack propagation region. Fabrication steps for CT specimens are described and a report is given both on crack propagation in the irradiated inserts and on quality control of CT samples.

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Facilities for the next century -

Fabrication of CT specimens with inserts of irradiated material by milling and EB-welding

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Abstract

The operational age of nuclear power plants is increasing. Nuclear power plant life extension studies are done to assure safe operation of the plants. In such studies further controlled mechanical testing of irradiated materials, i.e for crack propagation studies are needed. A consideration hereby is to do as much testing on as little material as possible. With this in mind the HBWR project specially designed miniature samples such as CTs with irradiated inserts in the crack growth region, fabricated suitable test samples and performed tests simulating BWR and PWR conditions, successfully.

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"Facilities for the next century"

Fabrication of CT specimens with inserts of irradiated materials by milling and electrobeam welding

by

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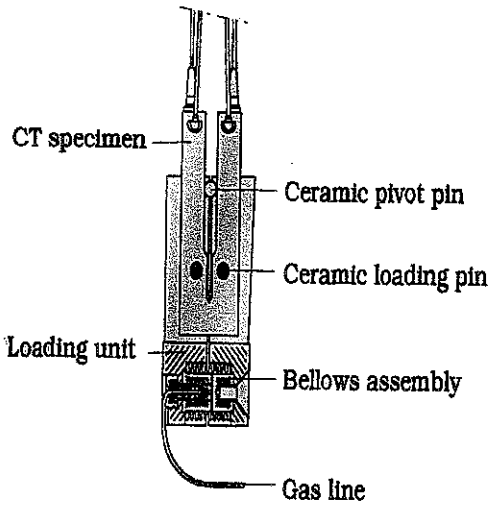
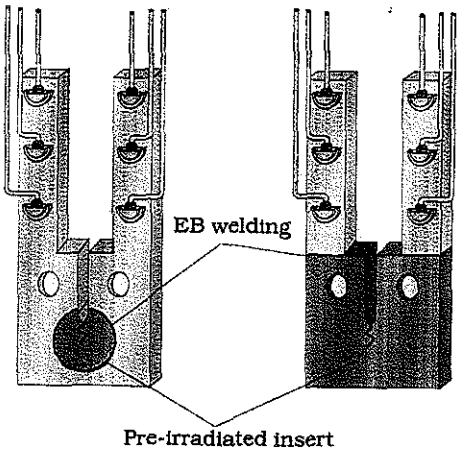
What are CT samples - what do we learn from CT sample testing?

- Compact tension (CT) samples are used in mechanical testing - Study of crack growth in materials (i.e. irradiated steels)
- *CT sample testing provides crack growth data* (crack propagation vs. stress intensity, vs. water chemistry)
- provides important information for nuclear power plant life extension studies
- enables prediction of irradiated material behaviour (i.e.reactor vessel material).
- allows possible counter-measures for crack propagation (i.e. water treatment) to be evaluated
- gives information on limits of operation for materials in existing commercial plants



What are CT samples with irradiated inserts?

- Limited availability of irradiated material (steels) for testing.
- CTs with an irradiated insert in the crack growth region are designed for obtaining data from a small piece of irradiated material.
- Two designs of CT samples are fabricated & tested in the HBWR under BWR, PWR conditions.
- CTs are designed and fabricated with round or square insert of irradiated material.

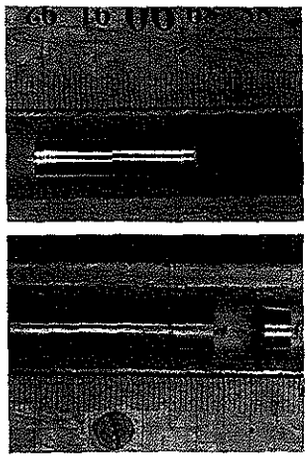


Steps in CT fabrication

- **Fabrication of non irradiated CT-body**
- **Cutting & preparation of discs or squares from irradiated material for CT-inserts**
- **Assembling of insert and body & electron beam welding of irradiated insert to non-irradiated CT-body**
- **Machining of surfaces of CT with insert**
- **Machining of chevron notch and side grooves**
- **Fatigue pre-cracking**
- **Installation in loading units fitted with pressurized bellows**
- **Spot welding of connectors for crack growth monitoring to arms of CTS**

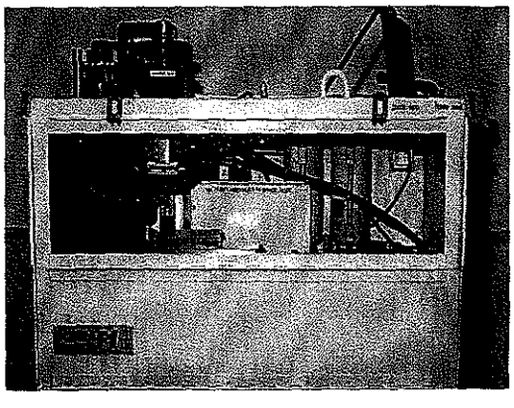
Cutting & preparation of irradiated CT-insert

- **Selection of irradiated material for insert**
- **Criteria:steel type, composition, heat treatment, irradiation history (thermal neutron flux, fluence, full power days,....)**
- **Geometrical adjustment of insert by cutting, turning, milling processes**

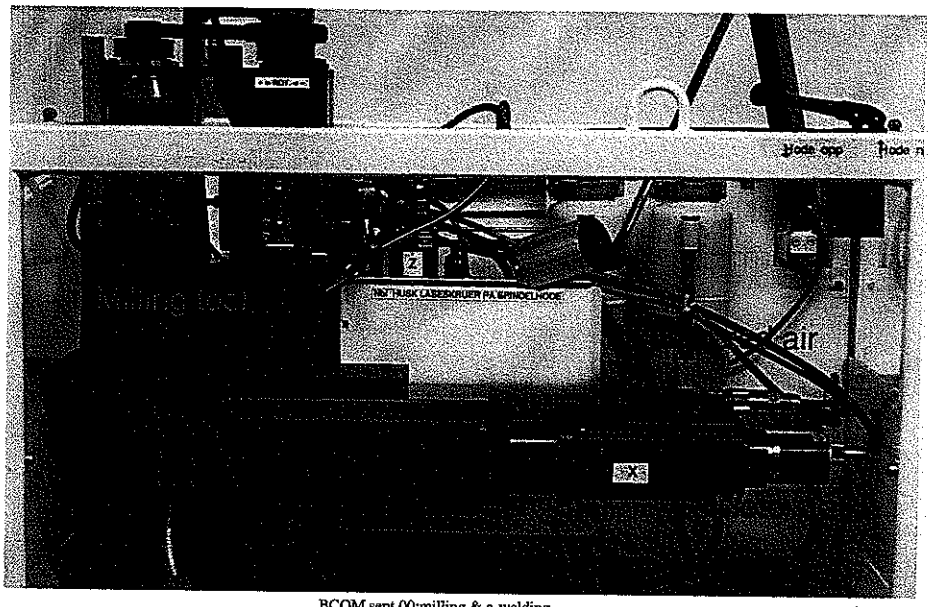


Remote handled milling machine in hot cell

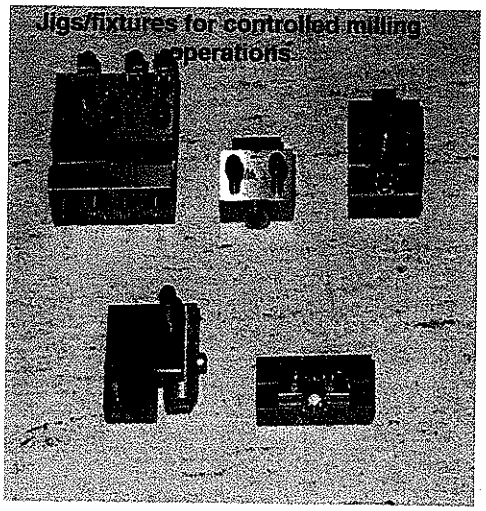
- For fabrication of test samples from irradiated material, i.e. CTs
- Modified, remote handled milling machine installed in concrete cell.
- The milling machine is operated with MS manipulators.
- Electric control unit and steering box separate from the machine.
- Special specimen jig and tool change fittings.
- The milling machine is installed in a containment box (milling particles)
- A central vacuum cleaner removes particles from milling

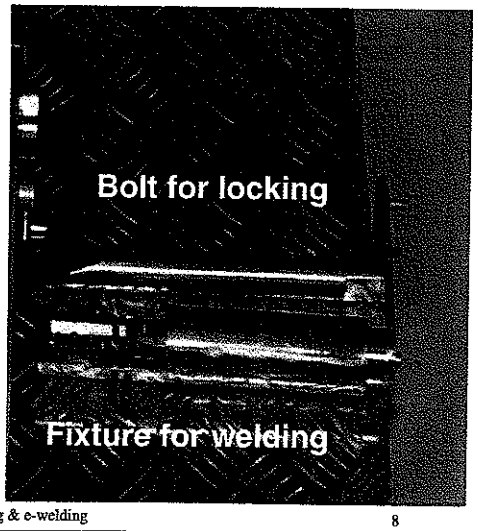


Remote handled milling machine

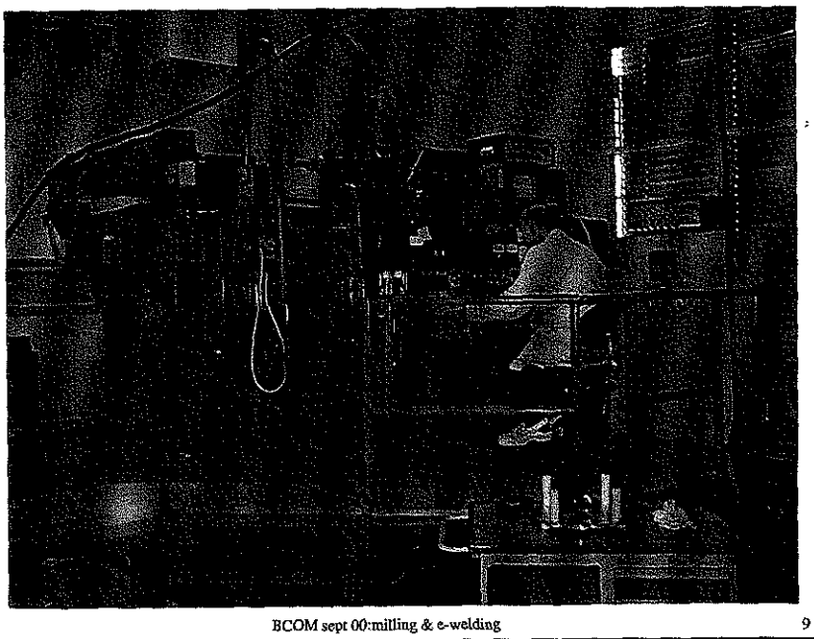


Special specimen jigs for milling & EB-welding

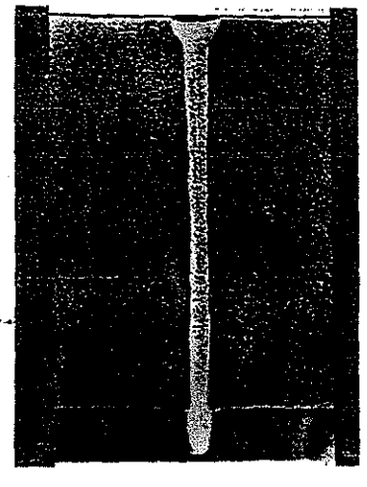




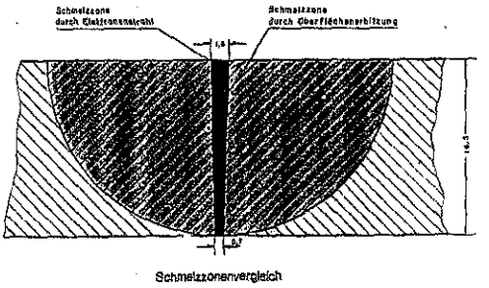
EB-welding machine



EB-welding



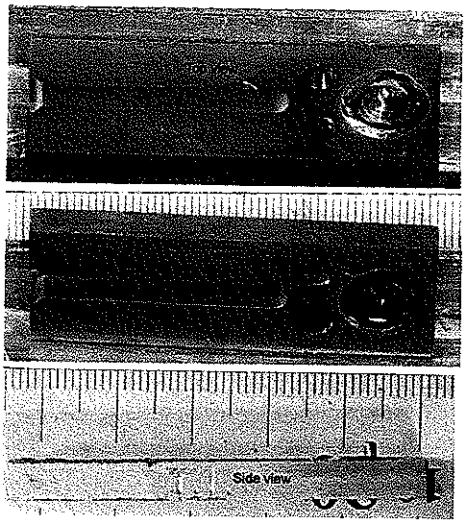
- **Deep narrow weld, narrow heat affected zone**



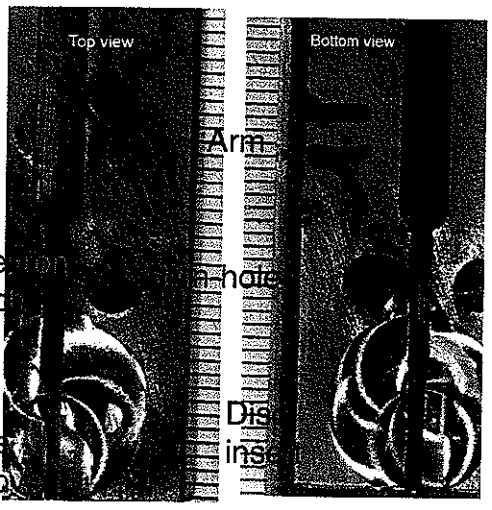
Schmelzonenvergleich

Electron beam welding of irradiated insert to non-irradiated CT-body

- **CT specimen is welded from both sides - welding depth ca. 3 mm**



Milling of welded surfaces, pin-holes, chevron notch & side grooves



Arm

Che
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Side
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Dis
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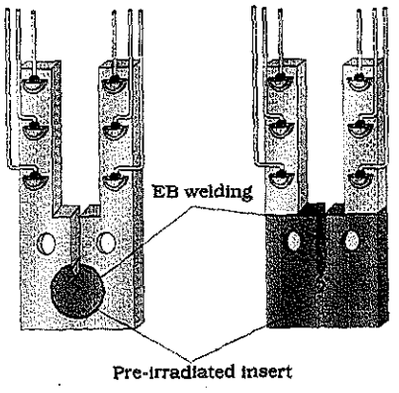
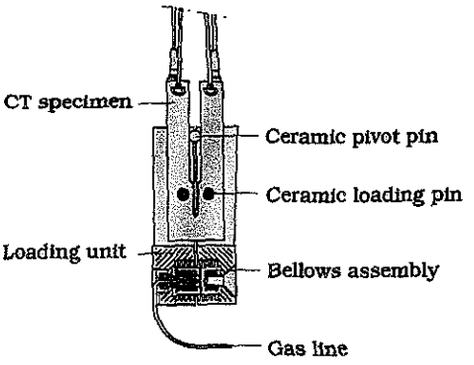
Square insert

Instrumented CT and mechanical loading of CT in reactor

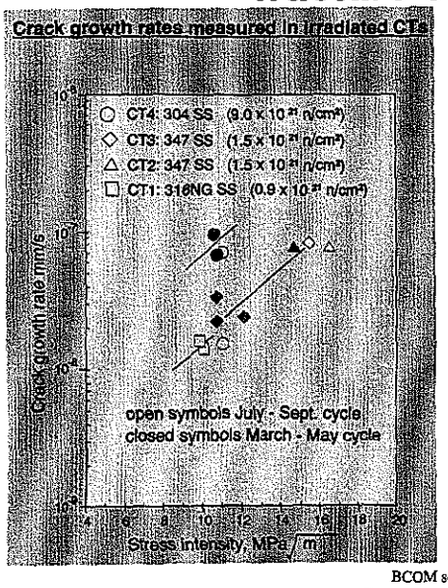
Spot welded connectors on CT arms for crack growth monitoring



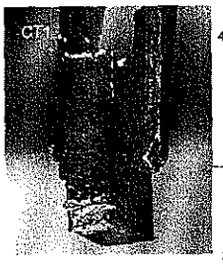
Installation of CT in loading unit fitted with pressurised bellows

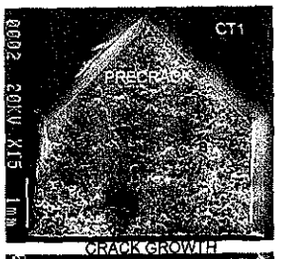


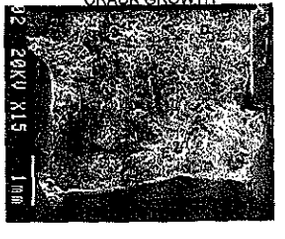
Crack growth vs. stress intensity & fracture surface morphology



CT with disc insert







Fracture surface

Facilities for the next century:

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Conclusion

- Nuclear power plant life extension studies demand machining of irradiated materials for further testing.
- The Hot Lab has enlarged its remote handled workshop capabilities for irradiated materials with a milling unit.
- The hot cell milling facility was described.
- Remote handled milling and EB-welding made fabrication of CTs with irradiated steel inserts in non-irradiated steel CT bodies possible.
- The fabrication for CT specimens was described.
- Crack propagation in CTs with irradiated inserts and PIE results were shown.