Our Experience with a Mobile Shielded Remote Handling System for Impact Testing of Radioactive Samples

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1. Introduction

An accelerated irradiation experiment was carried out in Fast Breeder Test Reactor (FBTR) by irradiating miniature Charpy V-notch (MCVN – 5x5x55 mm) specimens of SS316L(N) and SS304L(N) material to 2-5dpa. The purpose of this experiment was to compare the impact toughness properties of SS316L(N) and SS304L(N) under low dose irradiation conditions. The post irradiation examination of material irradiated in FBTR is carried out in the hot cells of Radio Metallurgy Laboratory (RML).

As requirement of impact testing of irradiated specimens did not arise earlier, the concrete hot cells did not house an impact testing machine. As there was no long term programme on irradiation of CVN specimens in FBTR, installing an impact test machine in hot cells just for one or two campaigns was not favorably considered. Instead impact testing was carried out using a mobile shielding system erected on the rear side of hot cells in an administratively controlled and ventilated zone. The hot cells are accessible from the rear side via a 900mm diameter man entry and 200mm diameter material transfer door by opening the mobile concrete shielding door. Impact machine was installed adjacent to the mobile concrete shielding door and a mobile shielded remote handling system was employed to shield against the radioactive specimens. The irradiated MCVN specimens were remotely taken out of hot cells through material transfer door, impact tested and sent back to the hot cells. This abstract gives a brief description about the impact testing campaign.

2. Activity Estimation and Shielding Calculations

The 24 pre fabricated MCVN samples irradiated in FBTRwas received in hot cells and dose measurement was carried out to estimate the activity. From a typical measured dose rate of 500 mSv/h on contact with a MCVN impact sample, the source term was calculated as 277.5 MBq activity of Co-60 point source. The configuration of the impact test facility was modeled using Monte Carlo code MCNP [1] and rigorous computing runs were performed to map the gamma dose rates around the shielded facility during the transfer and testing operations. The computation of doses were performed for the operating personnel involved in (i) sample transfer from cell to machine and back and (ii) sample loading & testing in the mobile shielded facility.

Radiation mapping of the mobile shielded remote handling system was conducted using a comparable activity Co-60 source and the dose rates were found to be in good agreement with the estimated dose rate values. Based on the analysis, the total dose estimated for testing of impact specimens was calculated to be 102.5PμSv per specimen for three persons. This dose was a conservative estimate with factor of two on maximum dose estimated and based on the time required for impact testing during mock up of the facility.

3. Impact Testing Setup Layout and Design

The major components of impact testing setup were (i) The impact testing machine, its controller and concrete foundation (ii) mobile shielded remote handling system (iii) Specimen transfer system (iv) Specimen Alignment Setup and (v) Peripheral Systems. The layout of the impact testing setup is shown in Fig 1.

(i) The instrumented impact test machine of 450J capacity was fixed on a 1.5t mobile concrete platform. The concrete platform had a steel plate above it on which specimen handling during transfer to and fro from the cell was carried out. The machine and concrete platform were wrapped in polythene sheets to prevent contamination of the machine components and steel structures. The controller and operator console was connected to the machine with 5m long cables so as to reduce the dose rate on critical electronic components.

(ii) The mobile shielded remote handling system (Fig 2) consisted of a 2m x 2m MS plate having 50mm thickness mounted on a frame structure having castor wheels. The shield had two master slave manipulators and a 900mm x 600mm glass viewing window. The shield also had a 3000 lumens LED and a PTZ camera mounted on the top side for aligning the specimen on the impact test machine anvil. The shield was placed at a distance of 1m from the concrete platform and space in between was covered with steel plates. The shield also consisted of a lead pot with effective lead thickness of 100mm, placed at the center of the shield near the concrete base for temporary storage of radioactive specimen. On the operator side of the shield, a TV screen was mounted to project live image captured from the PTZ camera. The machine console was fixed on the operator side of the shield. The machine controller was placed away from the machine so as to reduce the radiation field around the controller during active specimen handling in the shielded facility. The mobile shielded remote handling system was wrapped in polythene to avoid contamination.

(iii) The facility was located close to the hot cell wall to reduce the specimen transfer time. The impact specimen was taken out of the cells through a 200mm diameter door on the rear side of the hot cells accessible after opening the rear mobile concrete shielding for the cells. The specimen transfer system consisted of a 30mm thick steel pot attached to a 2m long steel pipe. The pipe was mounted on a pivot having capacity to slide. This steel pot was used to load the specimen in the cell using the MSM of hot cells, transfer it on the concrete platform and back to cell after testing. The pot was operated manually by an operator. A 2m distance was maintained between operator and steel pot during the specimen transfer operation to limit dose incurred by the operator.

(iv) Specimen Alignment Setup consisted of a screw-driven slide which pressed the sample against the anvil. The specimen centering tool was used from the other side of the anvil to mark the center of the anvil with a projection matching with the V notch groove of the sample. The specimen was aligned using screws to match the sample notch with the projection. As the groove on the MCVN sample is 1mm deep, PTZ camera was used to view the specimen during the alignment operation carried out using manipulators. The V notch groove of the sample was matched to the center of the anvils within ±0.25mm as per standard [2].

(v) Peripheral systems included area gamma scanners at critical locations, backup manipulator in case of manipulator failure during the operation, a crane to load and unload manipulator, and a lead shielded pot for temporary storage of sample in the event of breakdown of equipment.

4. Impact Testing

Extensive mock ups of the impact testing system were done and the working of manipulators and specimen handling systems was habituated. Time motion study was conducted to estimate time required for testing which was used for dose estimation. After mock up study, the components of the impacting testing system were installed in the rear side of hot cells. The machine was levelled and calibrated using standard NIST samples. Inactive samples were tested before commencing the testing on actual components.

Irradiated specimens were transferred from hot cell to the concrete platform using specimen transfer system. The instrumented impact test of the specimens were successfully conducted for 18 samples at room temperature by following the ASTM E23 standard [2]. The performance of SS316L(N) material under impact load was found to be superior as compared to SS304L(N) material. The results of the tests conducted are shown in Fig 4. Actual dose expenditure during impact testing was 6.4 PμSv per specimen for three persons. On completion of the testing, all the surfaces were checked for transferable contamination. Components such as tup and anvil had transferable contamination. These components were decontaminated and stored for future usage. All other components did not show any contamination and were dismantled successfully.

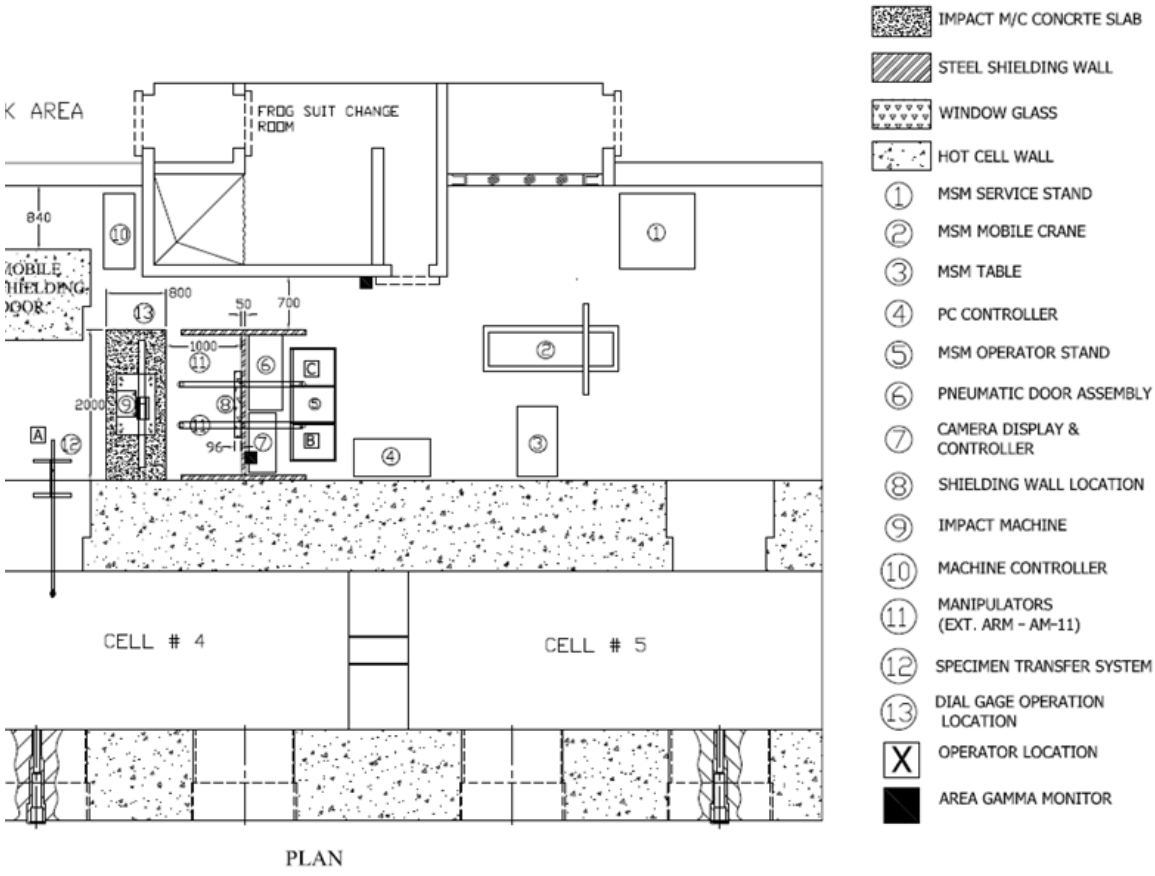

Figure 1. Layout of Impact Testing Facility

5. Conclusion

The impact testing of irradiated MCVN impact samples was completed successfully with minimal dose expenditure and spread of contamination using a mobile, shielded remote handling system. This system can be utilized to handle irradiated components of few mCi activity in case of limited hot cell .

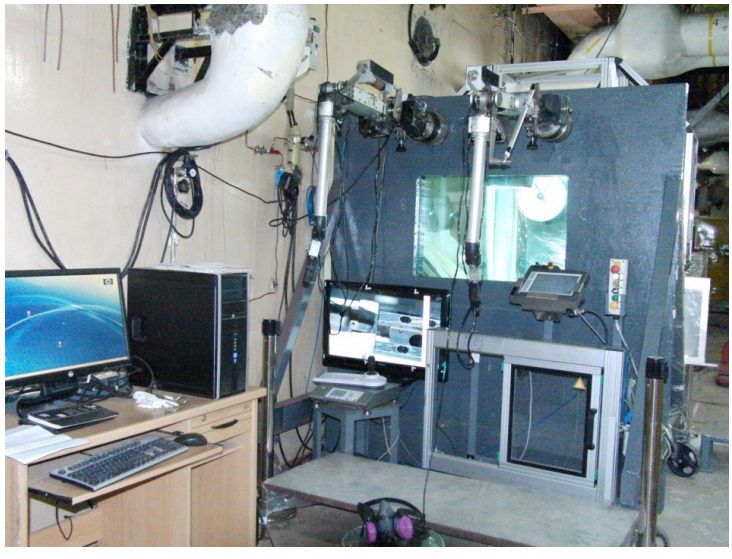

Figure 2. Mobile shielded remote handling system

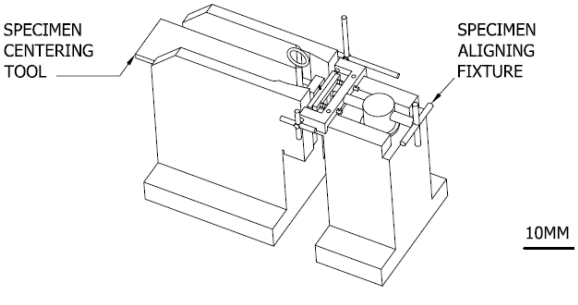

Figure 3. Specimen Alignment

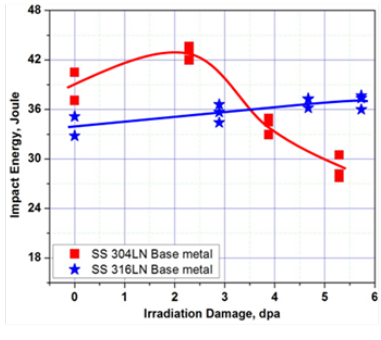

Figure 4. Impact energy values for tests conducted on active samples

6. References

1. J. F. Briesmeister, Ed., “MCNP - A General Monte Carlo N-Particle Transport Code, Version 4C,” LA-13709-M, Los Alamos National Laboratory, Los Alamos, New Mexico (April 2000).

2. ASTM E23 -16b, Standard Test Methods for notched bar impact testing of metallic materials