

MCNP simulations of neutron moderation in the IPNS C moderator

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Abstract

We have used the MCNP code to simulate neutron moderation in the IPNS target/moderator assembly. The goal of this study was to investigate the effect of groove configuration on neutron leakage from the C moderator. This moderator supplies low energy neutrons to four low-Q elastic scattering instruments; two reflectometers and two SANS instruments. The current horizontally grooved configuration is not optimized for the two vertical-slit-geometry reflectometers. This study resulted in a more optimized groove configuration. © 1998 Published by Elsevier Science B.V. All rights reserved.

1. Introduction

Monte Carlo methods are very useful in neutron transport calculations of complicated geometries and allow for a variation of geometric parameters without great difficulty. Most important IPNS target/moderator assembly components were incorporated into the MCNP simulation geometry used here, including; uranium target (pure U-238), reactor-grade graphite assembly structure, Be reflector, primary Fe shield, C moderator Al can and internal Al sponge (10% by volume), and C moderator Cd decoupler. An evaporation spectrum source was embedded in the U-238 target, thereby reducing computation time. C moderator consists of solid methane at approximately 20 K. However, we used

the free atom scattering kernel for monatomic hydrogen and carbon, with an atomic density and temperature corresponding to solid CH₄ at 20 K. Since we are only interested in relative changes in leakage current between various groove geometries, the use of the free atom scattering kernels is not expected to affect our conclusions. Scattering kernels for Be and graphite were used as well.

2. Results and discussion

The motivation for our study can be understood by considering the projections of the collimation system for each instrument onto the current moderator with horizontal grooves. The small angle instruments at $\pm 18^\circ$ view a large, circular portion of the moderator; a consequence of the converging-soller collimation geometry. The reflectometers have a vertical-slit collimation geometry and select

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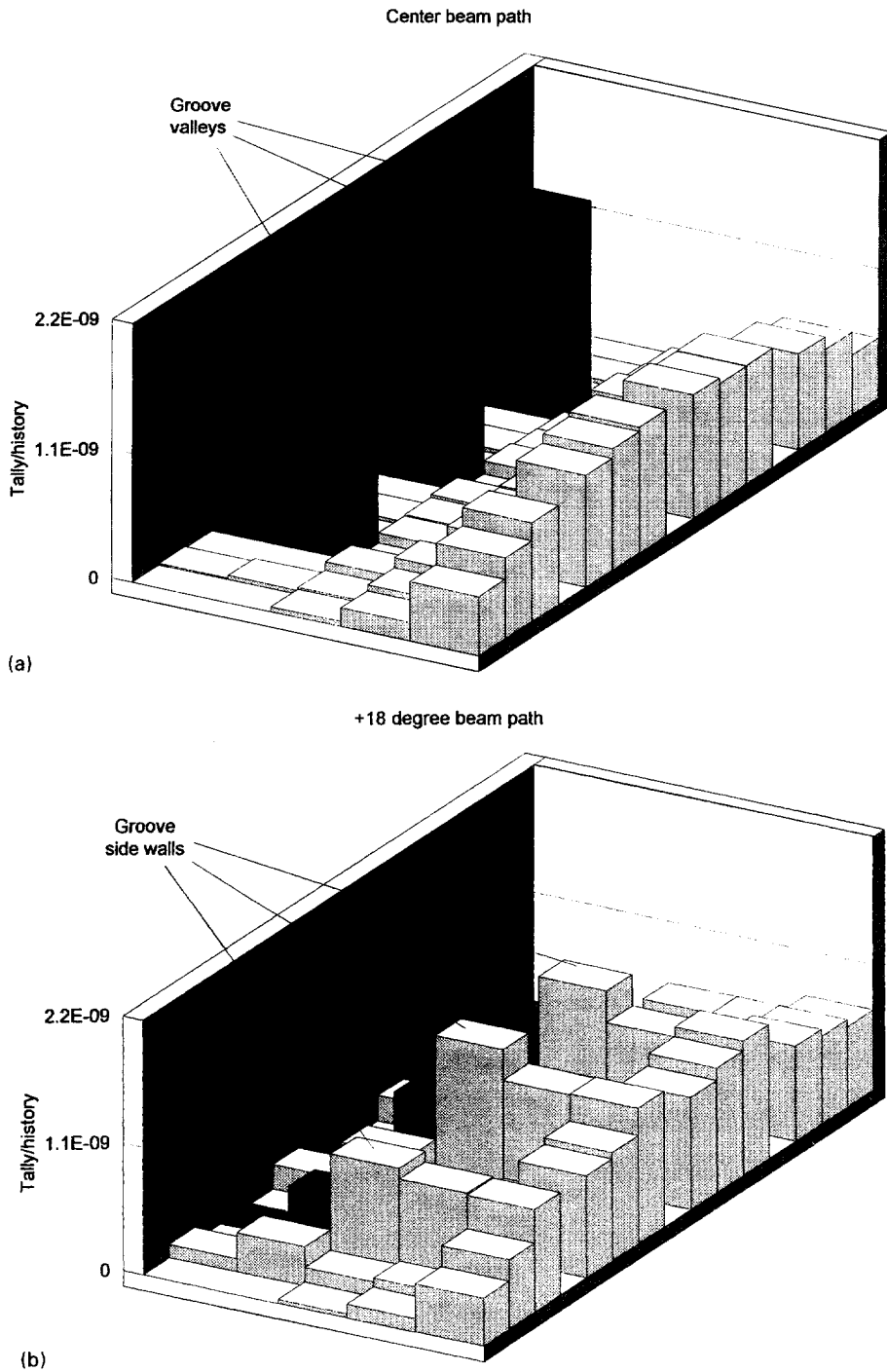


Fig. 1. Histograms represent a partitioning of a moderator with three vertical grooves into different cells. The cell of origin of each leakage neutron tracked during the simulation is plotted in the two histograms. In Fig. 1a, the valley regions (dark shaded) are seen to be the primary source of leakage neutrons down the center beam path to the reflectometers. At $+18^\circ$ in Fig. 1b, the valleys do not contribute significantly, as expected since the vertical groove configuration shields these regions. However, the valley shielding effect is compensated by stronger leakage from the groove walls.

Table 1
MCNP results for different groove configurations

Groove configuration	+ 18°/center ratio	Slit tally (arbitrary units)	Gain (relative to 5H)
5H	0.90	7.2 ± 1.0	1
5V	0.88	8.8 ± 1.1	1.2 ± 0.2
5VU	0.88	11.1 ± 1.3	1.5 ± 0.3
5VS	0.88	11.7 ± 1.3	1.6 ± 0.3
5VL	0.91	10.5 ± 1.2	1.5 ± 0.3

a narrow vertical strip near the center of the moderator. The reflectometer source is actually an average over the fin tips and groove valleys; the former a weaker source than the latter. A more optimized moderator configuration would allow each reflectometer to view more valley surface.

Simulations of the current configuration and a vertical-groove configuration were performed to investigate the effect of vertical grooves on the leakage intensity to the high take-off angle beam paths. It is known that the groove valleys, with a re-entrant geometry, are the strongest source of leakage neutrons. We expected the vertical grooves to shield the high take-off beam paths from the groove valleys, reducing the leakage current. However, we found that the high take-off angle leakage current was unaffected, as explained by Fig. 1.

This result indicated a new moderator could be based solely on vertical groove geometry. Four different vertical groove configurations were simulated in an attempt find an optimum design. All configurations had four grooves and five corresponding fin tips. All moderator geometries simulated had identical volumes. Table 1 summarizes the results for the simulations of five moderator

groove configurations. The first entry, 5H, represents the simulation results of the existing horizontally grooved moderator. The second, 5V, is the existing moderator configuration rotated 90°. The remaining three results are for vertical configurations with different groove widths and spacing.

The second column in Table 1 lists the + 18°/center ratio of leakage intensity for the five configurations. It is clear that the neutron intensity to the ± 18° beam paths is not degraded in the vertical groove configuration. The third column in Table 1 is a tally across a 0.63 cm wide surface or slit just downstream of the moderator face. The tally surface was placed in the exact location of the back projection of the POSY 2 reflectometer collimation system and is representative of the leakage source to the reflectometers. The last column in Table 1 represents an effective intensity gain (given by the ratio of the surface tally to 5H) to the reflectometers. Gains of approximately 50% are predicted.

MCNP was also used to simulate leakage pulse widths for all moderator configurations. The leakage pulse width was unaffected by the groove configuration, as expected under the constant volume constraint.

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