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FAST NEUTRON NUMBER ALBEDO CHARACTERISTICS FOR DOUBLE-LAYERED SLABS

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ABSTRACT

A Monte Carlo program was developed for the calculation of fast neutrons(14.1 MeV) albedo for point beam incident on single-layered slabs of carbon , iron and on double-layered slabs of iron-carbon , carbon-iron of varying thicknesses.

The difference between the behaviour of the number albedo of one- and two-layered slabs is very large and is strongly affected by the order of assembling the two layers as well as the relativethickness of each layer. Packing a layer of dens material with a light material layer increases the albedo value over the saturation value of the dense material.

1. INTRODUCTION

The complicated nature of the fusion design concept necessitates the incorporation of simplified radiation transport techniques which can easily be integrated with the plasma physics models to perform a complete parametric study. Fusion design is required to accomodate a variety of penetrations. The purpose and size of these penetrations vary depending on the reactor type. Radiation streaming into these penetrations can leadto adverse radiation effects such as nuclear heating and radiation damage. The albedo concept can be successfully applied for the analysis of radiation streaming into these penetrations. Adequate information on neutron albedos would allow neutronic optimization of the materials used for the first wall and blanket of the fusion devices. Also in the geometrically complicated neutron transmission problems, as in the multibend-air-duct transmission problems, the treatment could be simplified when albedo concept is used. The calculations could be carried out in two steps: first, calculating the angular distribution and energy spectrum of the reflected fast neutrons when a monoenergetic neutron beam is incident on an infinitely thick layer of wall material for various angles of incidence and neutron energies. The second step is the treatment of the real problem with its complicated geometry in which the wall material is replaced by a source surface having the previously determined reflection properties.

However, published analysis of the albedos for 14 MeV neutrons have apparently been limited to homogeneous media(2,3,5-7,13-19,21,22,24). Data for multi-layered media are scarce. Only two papers (25,26) considered the calculations of the neutron number albedo of double-layered slabs. In both papers, the S_N-method was used to calculate the albedos for double-layered slabs of iron and concrete. Measurements of albedos for double-layered slabs of iron backed by concrete and concrete backed by iron, and polyethylene backed by concrete were carried out (23) using a collimated beam of fission neutrons from Cf-252 source.

It is clear that the reported data to date cannot cope with the diversity of media and arrangements which are strongly needed for the nuclear systems design and analysis. In the present paper, a detailed study of the neutron albedo for the media: carbon, iron, and the double-layered media carbon -iron and iron-carbon was carried out using the Monte Carlo method.

2. COMPUTATIONAL METHOD

The neutron albedo properties of materials can be used to simplify neutron transport calculations or to aid in the design of nuclear systems by considering the neutron reflecting properties of various materials. Conventionally, the albedo is refered to as the ratio of the radiation current reflected from a surface to the current incident upon that surface.

A Monte Carlo program was developed for the calculation of fast neutrons (14.1 MeV) albedos for a point monodirectional beam incident on single-layered slabs of carbon and of iron and on double layered slabs of iron-carbon and carbon-iron of varying thicknesses. The history of the neutron is terminated when its energy falls below 0.5 MeV.Besides that carbon and iron are two relevant materials commonly used in nuclear systems,they present a good choice of a combination of light material and heavy material.

Since the fundamental mechanisms that result in neutron backscattering are elastic and inelastic scatterings, the simulation process of neutron histories in the media adequately accounts for the energy and angle dependence of these reactions as well as the other relevant interactions. The details of these interaction cross sections were taken from (4,8-12,20). The details of the Monte Carlo simulation of the neutron tracks were discussed in a preceding paper(1).

3. RESULTS

The sequence of ordering the two media of different weights in a double-layered slab has a strong influence on the magnitude of the albedos. Results for the t-cm-thick single iron layer and for the double-layered slab of t_1 cm iron(heavy material) as a first layer and t_2 cm carbon(light material) as the second layer are plotted in fig. 1 with respect to the thickness t_1. Curve parameter is the thickness t_2 of the second layer. The albedos for the iron slab increases monotonically with the slab thickness and reach a saturated value at a thickness of about 40 cm. For the double-layered slab, increasing the thickness of the first layer the albedo increases reaching a maximum value and then decreases to the saturation value of the iron slab. Increasing the thickness t_2 of the carbon layer(curve parameter) the albedo of the double-layered-layered slab increases. Relative increase in the albedo value is greater for smaller thickness of the first layer. This behaviour can be noted more clearly in fig.2, where the the thickness of the second layer is the independent variable while the thickness of the first layeris the curve parameter. It is found that taking a layer of finite thickness of a heavy material and backing it with a thick layer of a light material increases the albedo to a value greater than the saturation value of the heavy material. This procedure may be suggested when a maximum fractionof the incident neutrons is required to be reflected from the slab.

For the second case of ordering the light material as the first layer and the heavy material as the second layer(see fig.3,4), the albedo decreases monotonically with increasing the thickness of the first layer to the saturation value of the material of the first layer(see fig.5).

The strong dependence of the albedo values on the order of arranging the two media in the slab and on the thickness of each layer can be explained considering the difference in the moderating and the angular scattering powers of neutrons in the two media. The reflected neutrons can beconsidered to consist of two groups:the first group is those neutrons reflected after single- scattering collision, and the second group is the neutrons reflected after multiply-scattered in the medium.

The albedo for carbon is less than that for iron because carbon is characterized by its high moderating power together with its peaked forward sscattering. This difference in behaviour and its contribution to the albedo value can be noticedby evaluating the relative amounts of the three components constituting the neutron beam at a given depth in a medium. The three components are: the uncollided neutrons, collided neutrons passing in the forward directions(towards larger depths) and collided neutrons passing in the backward directions(towards the surface). The depth dependenceof the values of the three components in carbon and in iron was calculated and is given in fig.6 and 7 respectively.

In case of coating a light material with a heavy material, the relative number of the singly- scattered neutrons increases and the angular distribution of the neutrons entering the second layer is wider than their corresponding values in case if the material of the first layer were the same as that of the second one. Both factors result in increasing the albedo to greater value than that if the two layers were of the same kind.

In case of backing a heavy material with a light one, an increase in the albedo value over the saturation value of the heavy material could be achieved. Studying the angular distributions of the reflected neutrons from a single layered medium when a beam of neutrons is inclindly incident on its surface showed that for a carbon medium because of its peaked forward scattering to neutrons, most of the neutrons are reflected with directions making small angles with the normal to the surface(see fig.8). In case of iron most of of the neutrons are reflected with large angles with the normal to the surface. Thus in the case of double-layered, iron-carbon slab, the neutrons backscattered from the second layer in the first due to the small inclination of their directions to the normal will have larger probabilities to reach the surface than those neutrons if the second layer were of iron as the first layer.

Cocluding, the details of the albedo characteristics for double-layered slabs are much different than those for homogeneous media and precise values are needed to control the collided neutron current incident on double-layered slabs or in extracting neutron beams.

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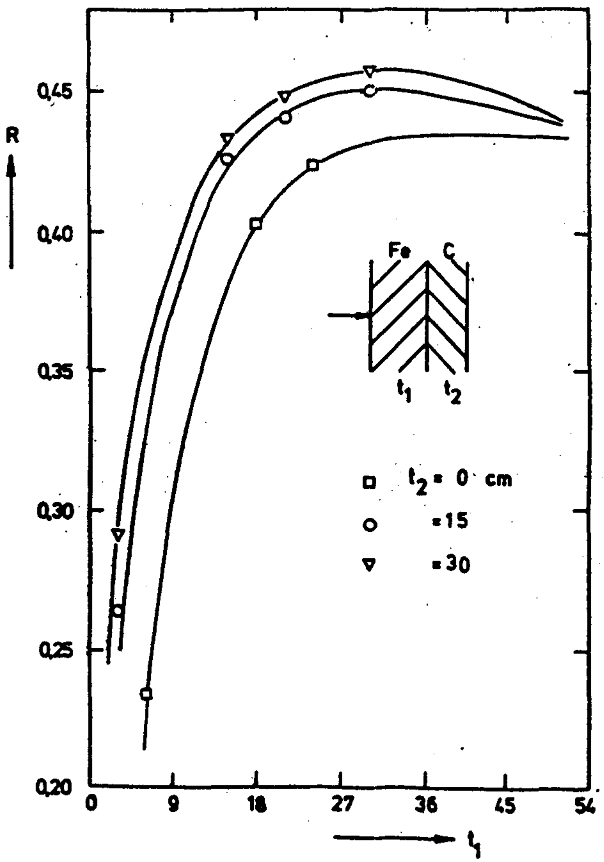
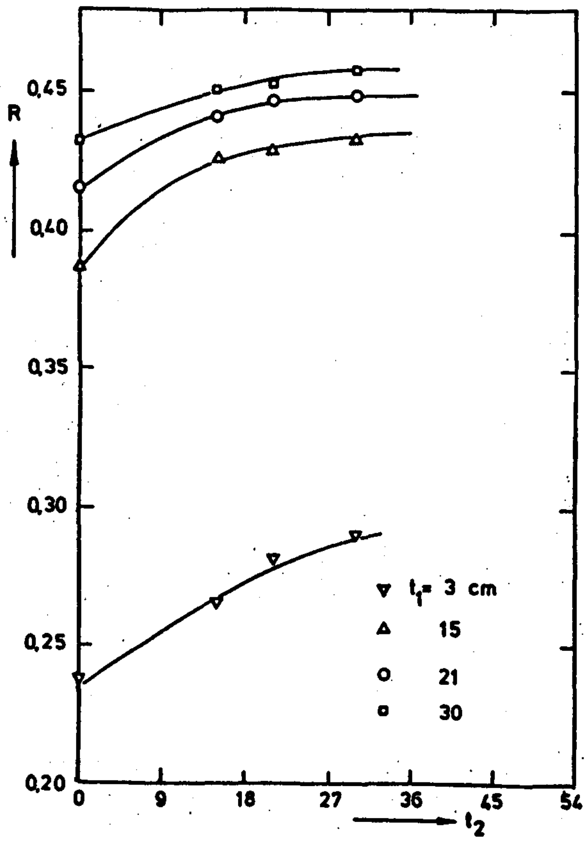


fig. 1 : Number Albedo R calculated for 14.1 MeV neutrons incident normally on the double-layered slab of t_1 cm iron + t_2 cm carbon. Curve parameter is the thickness of the carbon layer.



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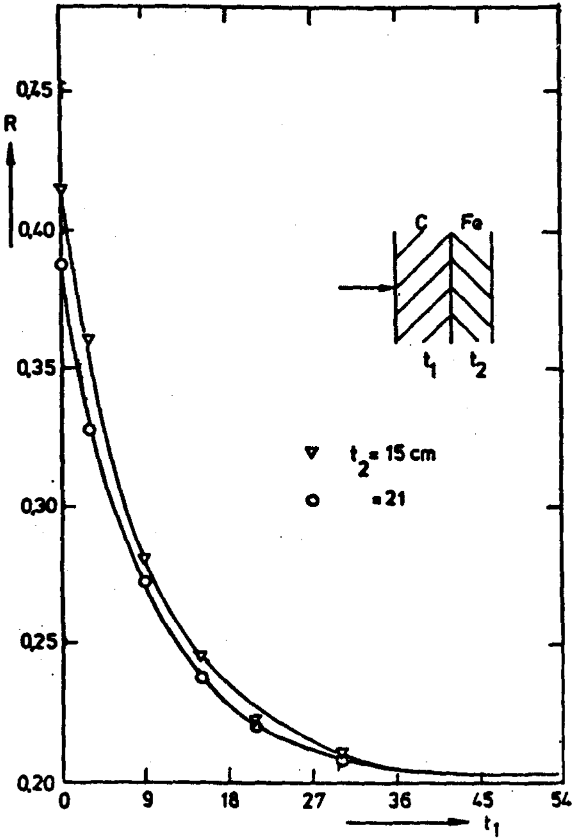

fig. 3 : Number Albedo R calculated for 14.1 MeV neutrons incident normally on the double-layered slab of t_1 cm carbon and t_2 cm iron. Curve parameter is the thickness of the iron layer.

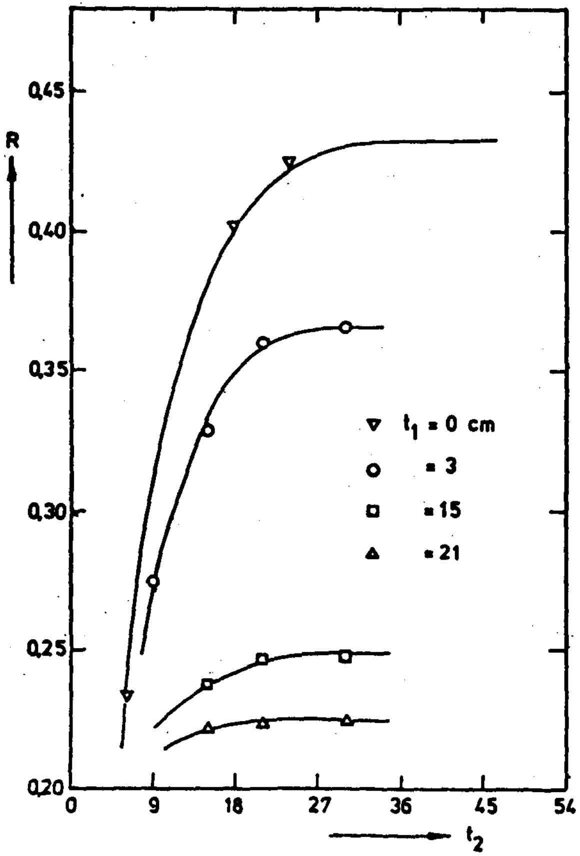

fig. 4 : Number Albedo R calculated for 14.1 MeV neutrons incident normally on the double-layered slab of t_1 cm carbon and t_2 cm iron. Curve parameter is the thickness of [illegible]

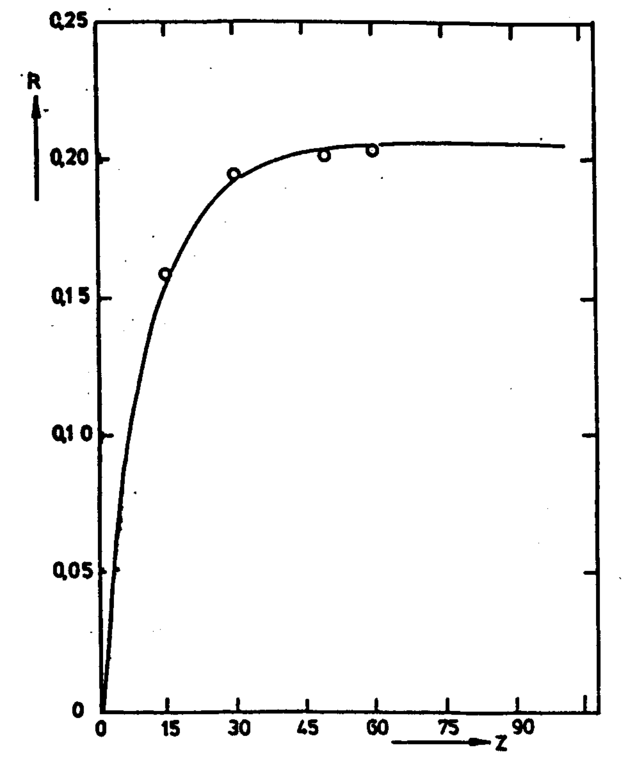

fig. 5 : Number Albedo R calculated for 14.1 MeV neutrons incident normally on a homogeneous slab of carbon of varying thickness z.

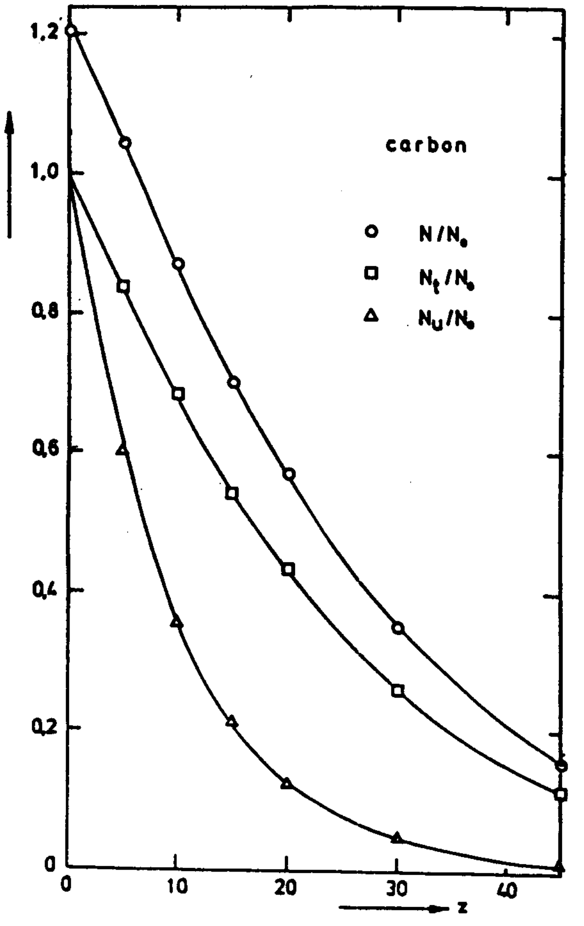

fig. 6 : Number of neutrons present at depth z in the irradiated carbon medium with 14.1 MeV neutrons. N_0 number of incident neutrons.

Triangles : uncollided neutrons.
Squares : forward penetrating neutrons.
Circles : total neutrons.

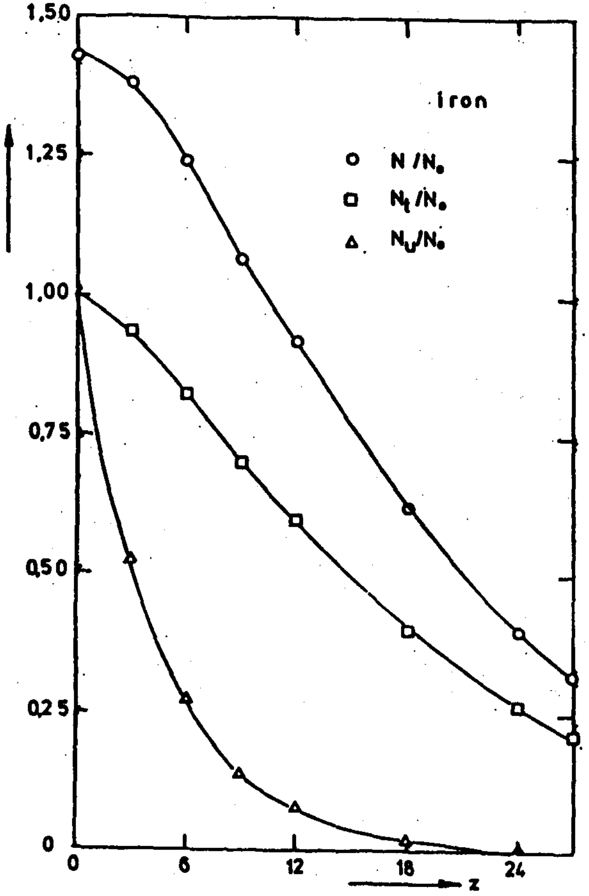

fig. 7 : Number of neutrons present at depth z in the irradiated iron medium with 14.1 MeV neutrons. N_o number of incident neutrons.

Triangles : uncollided neutrons.

Squares : forward penetrating netrons.

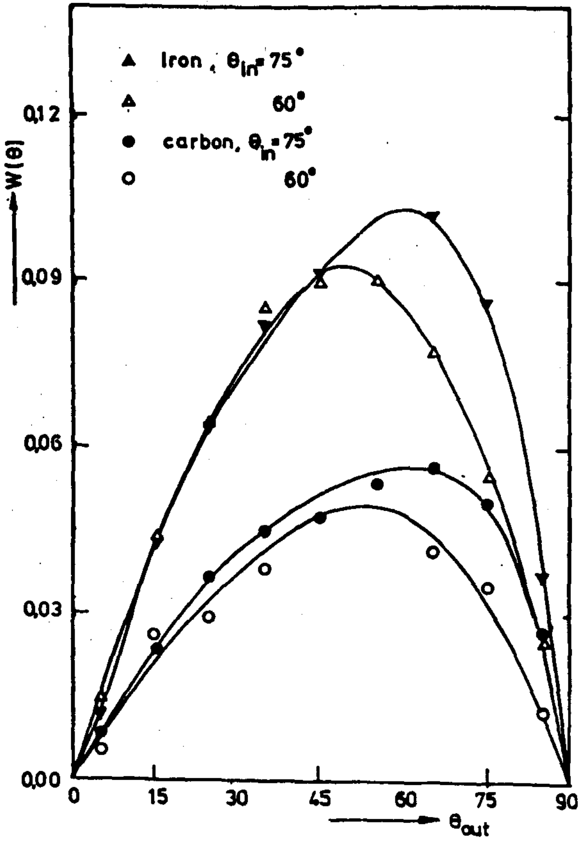

fig. 8 : Angular distribution of reflected neutrons. Curve parameter is the angle of incidence. N_o = number of incident neutrons.

Circles : carbon medium.

Triangles : iron medium.

$W(\Theta) = \Delta N/N_o \, \Delta\Theta$ = relative number of neutrons reflected at an angle between Θ and $\Theta + \Delta\Theta$.