DEVELOPMENT OF MATHEMATICAL AND EXPERIMENTAL MODEL OF NEUTRON RADIOGRAPHY SET UP

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Perspectives of mathematical modeling usage for neutron radiography set ups development are considered. Results of the calculation of neutron passing through plane polyethylene layer are given.

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Work on neutron radiography (NR) methods development was carried out in KIPT in 1999-2002 years. At this time world experience of NR application was studied, fields of its possible application, most perspective for Ukraine, was determined. Technical suggestions of such linac based set up creation was developed, technical requirements for such set up was worked out, different variants of its realization was considered, design drawings of NR set up module was developed, neutron flux diagnostics methods and NR images visualization by film method were worked out.

Application of neutron radiography method is most perspective in following branches of industry and science:

– atomic science – control of physics states (foliating, structure defects, fission substances flux changing, hydric substances and emptiness including), checking of irradiated fuel arrays, enrichment and sizes of fuel rod arrays with new and irradiated fuel, fuel rod arrays quality control, studying of nuclear fuel characteristics at different stages of new fuel elements models development, control of containers with radioactive wastes;

– space industry – control of subassemblies, consisting of isolation, plastic components, agglutinated units; pyrotechnic elements state (detonating devices, blow-out devices, gaseous charges and so on), moisture and corrosion detection, precision defectoscopy of the most important units, etc.;

– defense – control of blow-out charges, control of fuel state in solid-fuel rockets, control of subassemblies, engines construction optimization;

– aircraft technics – latent corrosion in aluminum constructions, water in hollows, latent defects in aircraft turbines, dynamics of liquid fluxes in aircraft engines etc.;

– automobile industry – dynamics of liquid fluxes in engines, control of moulds for wheel casting, etc.;

– turbine construction (control of turbine blades quality);

– science of materials – addition elements distribution, defectoscopy, including of hydric elements, other substances etc.;

– chemical and petrochemical industry – gaseous and liquid phases visualization, control of encapsulation quality etc.;

– ceramic industry(searching for cracks);

– heat transfer – visualization of gaseous and liquid phases action;

– geology – rock porosity, layers in sedimentary rocks, search for track quantities of oil etc.

First of all in Ukraine neutron radiography technology can be used for control of new fuel rod arrays model quality at their experimental operation (particularly, at realization of project "Ukrainian nuclear fuel", South-Ukrainian nuclear power station), during the development of new engine models, first of all aircraft ("Motor Sich" plant in Zaporozhye), for reliability increasing of space technics ("Uzhmash" plant in Dnepropetrovsk), for searching for defects and homogeneities in turbine blades ("Turboatom" plant in Kharkov) etc.

Gamma-radiography is known to be applied with great success for control of homogeneous objects [1]. At the same time neutron radiography gives large possibilities for inspection of the products of complex composition with hydric or other elements with large neutron interaction cross-sections [1]. Hence, at highly-precise linear accelerator it is principally possible to unite these methods and to obtain new possibilities of undestroying control of different products.

Researches and developments carried out in KIPT prepared the basis for experimental NR set up model based on linac. Such model is necessary for NR method optimization. It can be also used for solving of some above mentioned problems and also for practical demonstration of NR possibilities to potential customers. During the development it is necessary to optimize different units of NR set up (photo-neutron target, moderator, neutron beam generating system, photons and neutrons diagnostics system, modern system of image visualization, etc.). Optimization by experimental methods is very expensive and takes a long time. So it is necessary to develop mathematical model of NR set up and with its help determine required optimal parameters.

Reliability of obtained results will be checked by comparing of calculated and experimental results.

Variety of tasks, that can be solved with NR usage, can require different types of primary neutron sources (linac, neutron generator, isotope sources). That's why mathematical model will be also used for optimal NR set up for concrete tasks and conditions of potential customers.

So for NR set up development first of all it is necessary to develop programs, which simulate photons and especially neutron interaction with matter. These programs may be based on such well-known program-

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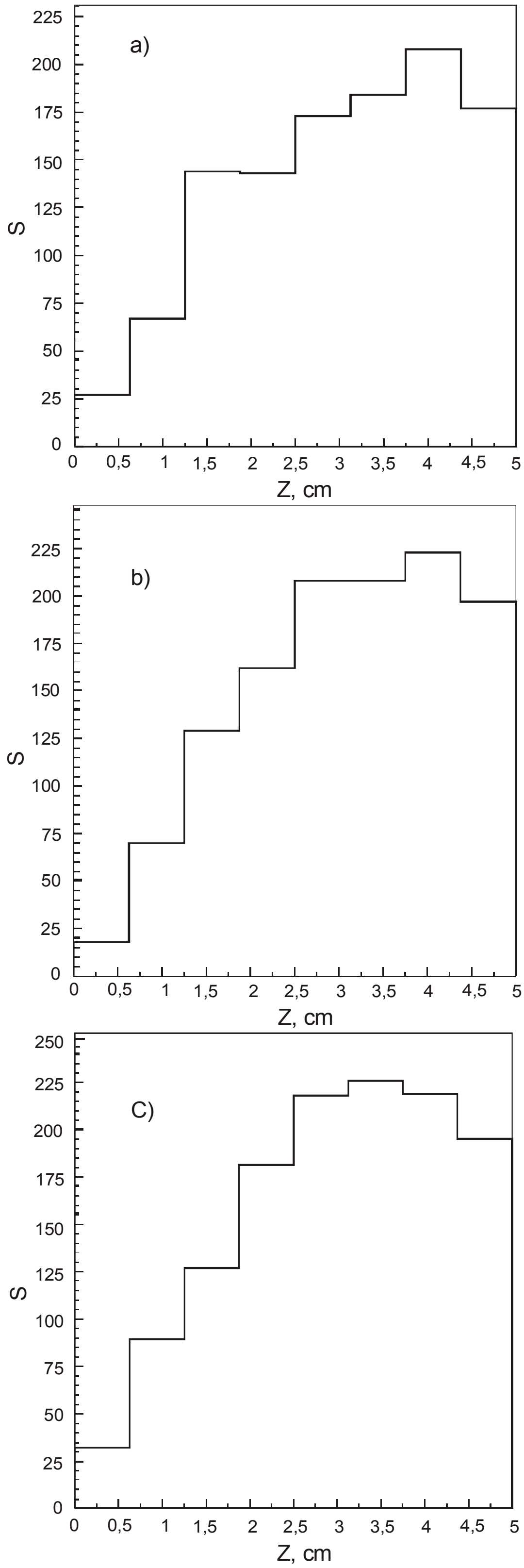

Fig. 1. *Thermal neutron sources distribution S as function of plane depth Z for initial energy 2 MeV and angles θ equal 0° (a), 30° (b), 45° (c)*

packages as GEANT3, GEANT4 and MCNP. Now many scientific departments in NSC KIPT have large experience of dealing with GEANT3, GEANT4 is studied and work with MCNP is planned.

As first step in mathematical modeling [2] of neutron interaction with matter we studied neutron passing through plane polyethylene layer. Monte-Carlo method and data on neutron cross-sections from [3] were used for solving this task. We took into account capture and elastic scattering because other processes have considerably less cross-sections. For thermal neutrons kinetic equation in diffusion approximation was solved [4].

Calculations have been carried out for parallel monoenergetic neutron beam with initial energy 2 MeV and angles θ between beam direction and normal to plane equals to 0°, 15°, 30°, 45°. As the results of these calculation we obtained thermal neutron sources distribution in polyethylene plane of 5 cm thickness (Fig. 1) and neutron spectrum after passing through polyethylene plane at different angles θ (Fig. 2). Obtained distributions are in good agreement with existing data [5].

So from obtained rerults one can see that in NSC KIPT works on realization of the above mentioned program on mathematical modeling of neutron radiography set ups are carried out.

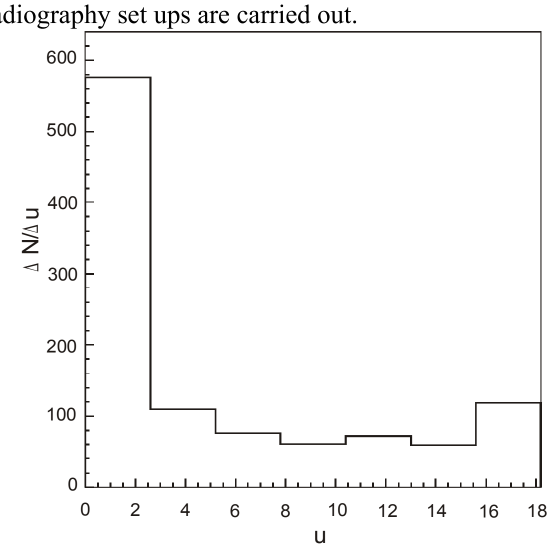

Fig. 2. *Neutron spectrum after passing through polyethylene plane with thickness 5 cm (initial energy 2 MeV, angle θ=0°, u – lethargy)*

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