THE ACCELERATOR RADIATION FIELDS EFFECTS ON THE COMPOSITE MATERIALS

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The radiation fields generated by accelerators are secondary to accelerated and transported particles and have complicated distribution in space and time. The accelerator radiation fields mostly are pulsed like the time structure of acceleration cycle and their space distribution have high gradient (10^2-10^3 Gy/m) [1]. The components and energetic structure of secondary radiation have a large energetic spectrum of secondary particles (Table 1),[2], defined by the type of accelerator, the geometry of initial radiation and materials interaction.

The composite materials used in accelerators lead to radiation damage of their structure and properties due to secondary radiation effects. Most sensitive are the organic and polymeric materials[3], which are used in accelerators as composite, hermetic, insulating, lubricant and other ones. The radiation lifetime of such materials is the ability to preserve their serviceability up to the limiting state, when the most important factor of the properties gradually changes to the fixed level, that is 0.5 of the initial value of the factor.

The radiation weariness is the result of monotonous radiation -chemical processes, continuously taking place in polymers used in accelerators [4]. One of the essential radiation lifetime points is the service time, e.g. the time of usage without failure in an exact system from beginning the operation to the limiting state condition.

Integral radiation doses (absorbed dose), which show service time of the materials are the factors of radiation resistance and can be defined only by experimental dependence "property factor - absorbed dose" for the definite levels of properties factor changing (Fig.1,2).

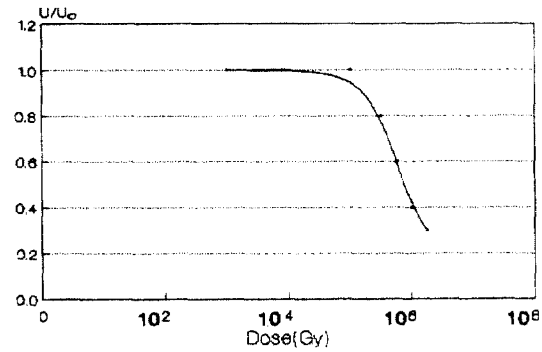

Fig. 1. Electric strength change of mica type after irradiation at the proton accelerator.

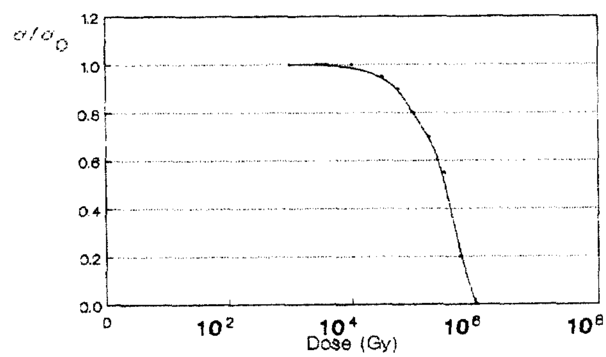

Fig. 2. Bending strength change of the micarta after irradiation at the proton accelerator.

Table 1. Characteristics of the accelerators as radiation source

The kind of accelerators	Accelerated Particles	Energy	The basic radiation	
			Before biolog. protection	After protection
Static-field accelerators, microtrons, betatrons, linacs	Electrons	< 15 MeV	Bremstrahlung	Bremstrahlung
		< 150 MeV	Bremstrahlung	Bremstrahlung fast neutrons, induced activity
Betatrons, synchrotrons, linacs	Electrons	> 150 MeV	Bremstrahlung	Bremstrahlung , E>50 MeV neutrons, induced activity
Static-field accelerators, cyclotrons, linacs	Heavy charged particles	< 30 MeV/nuc.	Fast neutrons	E<20 MeV neutrons, induced activity
Linacs, neutrons, synchrotrons	Heavy charged particles	< 10 GeV/nuc.	Hadrons	E>50 MeV neutrons induced activity
Synchrotrons	Heavy charged particles	> 10 GeV/nuc.	Hadrons, leptons	Hadrons, mesons, induced activity

The materials service time (T) prediction can be realized on practice only for the definite radiation field level (dose power) by the expression:

$$T = \frac{D_{0.25\ (0.5)}}{P}\ ,\ \text{hour}$$

where – $D_{0.25(0.5)}$ – the factor of radiation resistance defined experimentally (Gray)

– P – the dose power in the real geometry of the accelerator (Gray/hour)

The factors of radiation resistance and the materials service time for the different systems of 70 GeV proton synchrotron are given in Table 2. Since, the materials radiation resistance factor depends on the radiation type, the dose power and the radiation energy, the accuracy of the service time definition can be higher by using the experimental data like presented in Fig.1,2, which are measured in the correspondent conditions of irradiation of real accelerators.

The radiation doses of the materials can also damage the polymers. The materials of systems and basic equipment of Yerevan Physics Institute accelerator ring are in the secondary radiation field of complicated structure (bremstrahlung, neutrons, muons and so on). In the same time the materials are acted by mechanical and thermical loads, electric and magnetic fields, active chemical mediums.

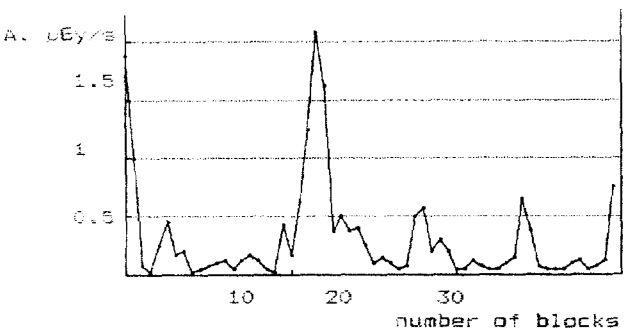

Fig. 3. Distribution of the residual activity A, on the vacuum chamber walls.

The highest level of secondary radiation act on that part of the accelerator ring, where the targets, injection devices, quadrupoles and sextupoles are located. In Fig. 3 the typical distribution of the residual activity on the vacuum chamber walls in Yerevan synchrotron is shown. The given distribution corresponds to extraction of gamma beam from channel 1 at the accelerated electron beam energy of 4.5 GeV and beam current of 3 mA. It is seen, that the activity is maximal in the area of 17-19 blocks, where the disturbing magnetic fields are generated for extracting the beams onto target, and also on block 1, while injecting the electrons into the ring. The integral absorbed doses in these points of accelerator during 20 year of its operation is about 5 MGy. Such level of the radiation doses is enough for some polymers to be damaged. For this reason lately in some sections of magnet blocks (17, 19, 20, 21, 24, ...) such insulating materials as epoxy compound and micarta have been damaged. In most cases the full change of damaged materials is impossible without the magnet blocks dismantling, and it means out of schedule shutdown of the accelerator . That's why it was tried to find such a radiation resistant material, which could stand for the damaged materials and allow one to restore the damaged insulation between the magnet blocks without their dismantling.

After analyses of more than twenty possible materials for the complex investigations there were chosen the monolith forming compounds on the polymer cement base. Their composition is presented in Table 3, and properties in Table 4.

Table 3. Composition of polymer cement

The names of components	Quantities in mass parts
1 Fast hardening cement	100
2 Quartz sand	100
3 Water	28
4 Epoxy resin "ЭД 2"	15
5 Hardener	4.5
6 Laproxyde 703	2.3
7 Oligoamid	1.5

Table 2. Prediction of service time of materials used in proton accelerators

Materials	Radiation resistance Gray [6-10]	Materials service times in different systems, hour		
		Vacuume chamber P = 300 Gy/hour	Magnet coils P = 50 Gy/hour	Cable routing P = 15 Gy/hour
Ftoroplast-4	10^3	3.3	20	66
Mineral oil	10^4	33	200	660
Textolite	$2*10^5$	$6.6*10^2$	$4*10^3$	$1.3*10^4$
Natural rubber	$2*10^5$	$6.6*10^2$	$4*10^3$	$1.3*10^4$
Polyethylene	10^6	3 300	20 000	66 000
Textolite glass	$2*10^6$	$6.6*10^3$	$4*10^4$	$1.3*10^5$
Epoxy compound	$5*10^6$	$1.6*10^3$	10^4	$3.3*10^4$
Cement base compound	10^9	20 year	20 year	20 year

Table 4. Physical and chemical properties

Compression strength, MPa	50-80
Bending strength, MPa	11-12
Adhesive bending strength, MPa	4.1-5.2
Relative tensile deformation, %	0.087-0.004
Modulus of elasticity, MPa	$(2.05\text{-}2.27)*10^4$

For getting more adhesion of polymer cement compound, the damaged surface was cleaned from oil and abraded, then covered by adhesive ground, which consisted of: resin - 100 m.p., plasticizer - 10-15 m.p., hardener - 12-20 m.p. The monolith formation continued for about 2 hours to get the hard state of the compound.

So, there are shown the possibilities of calculations of the radiation doses in accelerator irradiation conditions, the definition of service time and the use of polymer cement compound as a restoring material for the radiation damaged elements of Yerevan electron accelerator.

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