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The Effect of Electron Beam Irradiation and High Intensity Magnetic Field on Deformation Properties of Polymer Composite Materials

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Abstract: An experimental study of radiation-modified blends of high-density polyethylene (PE) and ethylene propylene diene rubber (EPDM) exposed at constant magnetic field (MF) with induction B equal to 1.0, 1.4 and 1.8 T is presented. Materials have been irradiated with accelerated electrons with absorbed doses equal to 100 and 150 kGy. The main focus of the research is devoted on deformation (elastic and viscoelastic) properties of polymer materials. The gained data show effect of the absorbed dose and magnetic field induction on the modulus of elasticity E and the creep of the investigated polymer composites under the influence of constant tension. Decrement of elastic modulus and increase of total deformation of unirradiated polymer composites has been observed with increase of the induction B. The effect is reduced by increase of the absorbed dose of electron beam radiation to 150 kGy. The value of E remains almost constant for cross-linked polyethylene, in contrast to the non-irradiated samples, at induction in the range of 0.5 to 1.8 T. Radiation modification and increment of the EPDM content of EPDM minimizes the effect of the magnetic field on elastic properties of materials. Changes of crystallinity and melting temperatures of polyethylene in composites have been investigated to better explain the effect of cross-linking and the compatibility of both the components in investigated materials.

Key words: Polyethylene, EPDM rubber, electron beam radiation, magnetic field, deformation properties.

1. Introduction

Polyolefin based materials and multiphase blends made of polyethylene, propylene and polyolefin copolymers are commonly used due to industrial applications as manufactured products, insulation and packaging materials. Synthesis of ethylene copolymers, especially terpolimerisation of ethylene propylene with dienes by a Ziegler-Natta catalytically systems started in the middle 1960s-1970s [1]. The main aim was to synthesize improved rubber materials with a high durability and better mechanical and thermal properties in comparison to conventional rubbers like butadiene rubber, neoprene, chloroprene etc. [2-4]. Ethylidene norbornene and dicyclopentadiene are the two most used dienes in EPDM rubbers nowadays.

High density polyethylene, EPDM rubbers and binary composites made of them are widely applied as electrical insulation materials (power cables, wires, moulded electrical accessories, etc.) with superior electrical properties, resistance to thermal shock, flexibility over a wide temperature range, especially low temperature flexibility, resistance to humidity and optimal mechanical properties [5].

There is scientific and practical interest to study the influence of magnetic field on the mechanical

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properties of these materials before and after exposure to ionizing radiation.

Although the theoretical studies of effect of various types of high energy radiation (X-rays, accelerated electrons, γ-irradiation, the fast and slow neutrons, protons, and other products of nuclear reactions) on polymer materials have been studied since the 1960s of the last century, investigations of cross-linking and scission processes on the properties of polymers are still urgent [6-7].

There are two competing processes that are accompanied by polymers during the irradiation-the cross-linking that affects as increase in thermal, mechanical properties, and the other process-degradation of polymeric macromolecules as a result of radiation induced chain scission.

Physical and mechanical properties of EPDM can be significantly improved by the chemical cross-with peroxides, a well used method up to nowadays for cross-linking EPDM and grafting it with other polymers [8-9]. Despite the popularity of this method, there are many complicated parameters to optimize efficiency of different peroxides due to different decomposition kinetics of them, homogeneity of the vulcanization, controlling the concentration of unreacted peroxides etc. [9].

Modification of polymers by ionizing irradiation (X-rays, accelerated electrons) can significantly improve the durability of EPDM by the radical induced cross-linking [10-11]. Electron beam (EB) irradiation has many advances (small irradiation time, low dose rate, reduced oxidation during irradiation that allows precluding processes of chain breakage).

Despite the fact that polymers are non-magnetic materials, which have no magnetic moments, in recent years, an increased interest has been attributed to the effects of constant and impulse magnetic fields on the physical, chemical and, in particular, the mechanical properties of polymer materials. The reason for such a theoretical and practical interest is attributed to the modern fields of engineering. Some of the applied aspects include magnetoplastic effect (MPE) under the influence of even a relatively weak magnet fields with magnetic induction B equal to 0.1-1.0 T on the deformation properties mainly on crystalline and semi-crystalline polymers (increase of creep, decrease of mechanical properties like elastic modulus, the yield stress, strain at the break and microhardness) [12-17].

These phenomena are important from a technical point of view, because of intensive research and construction on controlled thermonuclear fusion reactors like the International Thermonuclear Experimental Reactor (ITER), the Demonstration Power Plant (DEMO) and the other future fusion reactors based on magnetic confinement of plasma in a magnetic field over 1 Tesla.

There are a lot of design elements in reactor materials, including polymer materials based on cross-linked high density polyethylene and composites with elastomers like ethylene propylene rubbers, epoxides, polyether and liquid crystal polymers that often have mechanical loadings [16]. These materials are used as insulations and coatings like electrical wire insulators, sealants, membranes, O-rings, gaskets and other devices [16, 18-23]. The main prerequisites for the use of these materials for nuclear applications are thermal stability (resistance to a working temperature over 90 °C), excellent dielectrically properties, resistance to long-term radiation exposure (neutron, γ or electron beam radiation) and of course great mechanical properties.

High MF (B equal to 3-5 T) is also used in radiation detectors coated with polymer cables etc.. In all these areas pseudo plasticity induced by MF is an undesirable process. Therefore, research into the reduction or complete suppression of these effects is highly relevant.

The increased interest in the studies is related to the fact that the observed effects cannot be explained in terms of classical thermodynamics. According to a theory [24] a very strong MF requires with the induction of 100-1000 T, to affect the deformation

properties of polymers at room temperature. The Zeeman energy of splitting $\mu_B H$ (μ_B-Bohr magneton, H-the strength of MF) characterizing the splitting of spectral lines and energy levels of atoms, molecules and crystals in a MF should be comparable or greater than kT (k-the Boltzmann constant, T-the absolute temperature) to affect any properties of polymer materials. This means that the spin reorientation at room temperature in a MF requires energy, which exceeds the average energy of thermal fluctuations and these strong MF applied in the practice that rarely exceed 2-10 T cannot lead even to the heating of polymers, therefore, cannot create plasticity. However, that is not confirmed by actual experiments in the study of polymer deformation properties in MF of 0.2-0.5 T, described, for example, in Refs. [12, 16] and in other studies.

Physical methods mainly based on the studies of electron paramagnetic resonance [25] have showed a high anisotropy of the diamagnetic susceptibility of the polymer chains and have revealed the presence of internal local MF in a small regions of ordered polymer ("physical units") with non-chemical interaction between the adjacent molecular groups in macromolecules [12-16].

The authors of Ref. [16] believe that the effect of pseudo plasticity is attributed to formation of the induced magnetic moments and their rearrangement, i.e. the change of direction by unpairing of radical centres that promotes the formation of free radicals in the locations of structural defects. Later in the development of these defects, nano-cracks and micro-cracks may occur that cause an increase in the deformability of material and accelerate its destruction by mechanical loading.

The authors of Refs. [26-27] have found that the orientation action of MF during the tension in respect to elastomer macromolecules can lead to appearance of so called elastic forces during the elastic strain in MF contributed to micro Brownian motion that leads the ends of chains of elastomer molecules moving closer each to other. That appears as increment of time of deformation, respectively, increment of deformation in contrast with the material strained in the absence of MF. The authors attribute it to elastomers more sensitive to MF containing unsaturated bounds like double or triple bonds and polar functional groups like nitrile and halogen groups that affect the magnetic susceptibility [17].

It should be noted that the physical nature and mechanisms of action of MF on nonmagnetic materials are still largely unclear. In the current work we investigated effect of MF on HDPE/EPDM composites.

Some other physical parameters (degree of crystallinity from X-ray diffraction data, melting temperatures from endothermic peaks in differential thermal analysis curves) also have been researched.

2. Materials and Methods

2.1 Materials

High density polyethylene (HDPE) of trademark 20708-016 (degree of crystallinity χ_c-57.9%, ρ-0.945 g/cm^3) obtained from the Novopolotsk Chemical Enterprise, Belarus, and ethylene-propylene-diene terpolymer (EPDM) of trademark EPDM-40 (Russia) with a density 0.87 g/cm^3 and a content of propylene 40 mole% and dicyclopentadiene 2 mole% have been used in composites .

Blending of HDPE with EPDM was carried out by thermoplastic mixing at 160 °C for a total duration of 4 min. Compression moulded blends were obtained at the temperature of 160 °C and at a pressure of 5 MPa. Specimens for the tensile and creep tests were cut down from the blends in the form of double-sided blade with a length of the working area 20 mm, the thickness of the blends varied from 0.5 to 0.8 mm depending on the composition. The content of EPDM in binary composites of HDPE/EPDM was in a range of 0-80 wt%.

2.2 Methods

Blends were irradiated in linear particle accelerator with accelerated electrons (energy 5 MeV, dose rate

1.2 MGy/h) in air with absorbed irradiation doses D_{abs} equal to 100 and 150 kGy.

Creep tests of samples were made in the creep measurement apparatus consisting of a stand made of non magnetic stainless steel of trademark 12X18H10T (Russia). The construction of apparatus is shown in Fig. 1. The loading is located between the poles of an electromagnet obtained from nuclear magnetic apparatus of trademark TESLA BS 497 (Czechoslovakia) with an induction B in the range from 0.6 to 2.5 T. The loading for a permanent mechanical stress is made of chemically pure cathode copper (grade MOOK, Russia), containing impurities, (not more than 0.001%). Axis of the sample material was perpendicular to the vector of MF. Deformation was measured by a digital indicator of trademark MarCator 1086 Z supplied by Marh (Germany), which has a resolution of 0.001 mm and is equipped with a computer program MarhCom-Software (version 2.0) for measurement of data process.

The short-term creep tests were carried out under the action of constant loads for 10 minutes at 22 ± 0.5 °C temperature. Mechanical loading of composite samples was carried out in the absence of magnetic field and in magnetic field with induction B equal to 1.0, 1.4 and 1.8 T. These tests were performed only to investigate the creep in the linear region of stress-strain relationship. Creep tests were conducted at a constant mechanical stress σ_o equal to 2 ± 0.5 MPa. Difference of the thickness of blends at different ratios of EPDM was taken into account-the changes of deformation were calculated against the mechanical stress values in the form of compliance curves $D(t) = \varepsilon(t)/\sigma$, MPa^{-1} to compare the results of specimens at different ratios of EPDM.

The quasi-static elastic modulus was determined from the results obtained in a fast stepwise loading of samples measured at the loading time of strain ε_o equal to 2 s. The elastic modulus was defined as the ratio between the stress applied and the strain measured. Five parallel measurements have been done.

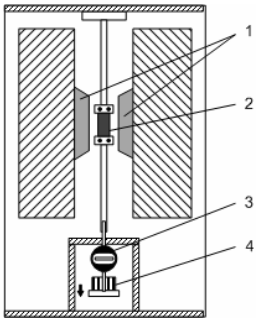

Fig. 1 Scheme of the test setup for the investigation of short-term creep of polymer samples in a magnetic field: 1-poles of magnets, 2-a sample, 3-digital indicator for measurement of deformation, 4-the loading.

Changes in the crystalline content of high density polyethylene in HDPE/EPDM composites were calculated by X-ray diffractometry on the Bruker D-8 Advance X-ray diffractometer at room temperature. The CuK_α wavelength (λ = 1.540562 Å), with monochromator was used as incident radiation at measurement conditions 40 kV and 40 mA. Patterns were recorded by monitoring diffractions from 10° to 40°, and the scanning speed was 0.5°/min.

Differential thermal analysis (DTA*)* was carried out on the Seiko ™ instruments Incorporated SII Exstar 6000, TG/DTA 6300 using approximately 10-15 mg of material accurately weighed in to an aluminium sample pan. An empty aluminium pan was used as a reference. The specimens were heated in air atmosphere in the temperature range from 30 °C to 300 °C at the heating rate 10 °C/min. Analysis of the melting temperatures was carried out using the Seiko ™ instruments Incorporated SII Exstar 6000, TG/DTA 6300 dedicated analysis software.

3. Results and Discussion

3.1 Creep Tests in Magnetic Field

First, an investigation was made to see the changes in the creep of unirradiated and irradiated entire high density polyethylene at a constant stress equal to 2.2 MPa. Creep was measured with no additional effect of MF and under the influence of the field with induction B equal to 1, 1.4 and 1.8 T.

Kinetics of increase of deformation with time under the influence of constant tension for HDPE is shown in Fig. 2. In the form of compliance curves $D(t) = \varepsilon(t)/\sigma$, where, D is the creep compliance, and t is the time. The creep compliance curves for unirradiated and irradiated up to 100 and 150 kGy HDPE confirm that the effect of magnetic field on the creep of the material is highly significant.

Achieved total deformations of unirradiated polyethylene are significantly increased after the time of loading under the influence of magnetic field in comparison to measured in the absence of it. The values of creep compliances measured at 1.4 T and 1.8 T were 1.5 and 2.1 times greater in comparison to D(t) recorded in the absence of the field. It is notable that this result is consistent with the data of Ref. [15], where an increased creep deformation rate of some amorphous and amorphous-crystalline polymers were found under the influence of significantly lower MF (B = 0.2 T).

The deformations tend to decrease (see the curves b and c in Fig. 2) by increase of the radiation dose. It is contributed to increase of the strength of cross-linked macromolecules of HDPE, the forces between the cross-linked moieties reducing the extension of macromolecules. It is clearly seen in Fig. 2 that the radiation modification of the samples led to a significant modification not only on reducing the deformability of material, but also effectively minimized the effect of MF on the creep. This is evident from approach of the curves each to other (see Fig. 2c). For example, the value of D(t) at radiation dose 150 kGy in a MF with induction 1.8 T were 60% less in comparison to the value of unirradiated samples.

Dependence of instantaneous total creep compliance D(t) and elastic modulus E on induction of MF in the creep tests for 10 minutes for unirradiated specimens and irradiated with 100 kGy and 150 kGy is seen in Fig. 3.

Elastic modulus noticeably decreased with increase of induction while the values of D(t) tended to increase. For unirradiated sample elastic modulus has decreased 2.7 times and the total creep compliance D(t) has increased 2.1 times at induction equal to 1.8 T in comparison to the values observed in absence of MF.

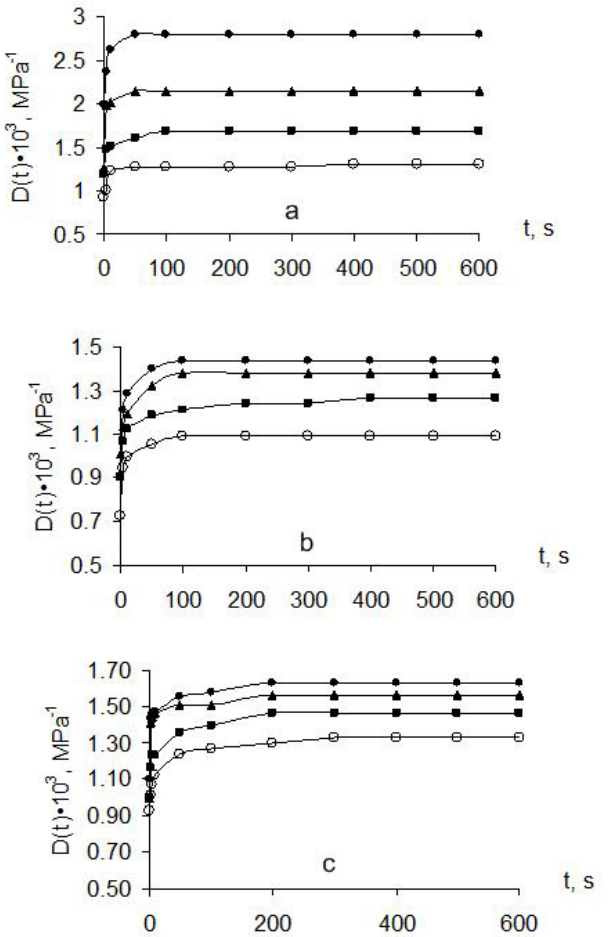

Fig. 2 Experimental curves of total creep compliance for (a) unirradiated and irradiated with (b) 100 kGy and (c) 150 kGy. HDPE measured in the absence of magnetic field (o) and in a constant magnetic field with induction B equal to 1 (■), 1.4 (▲) and 1.8 T (●).

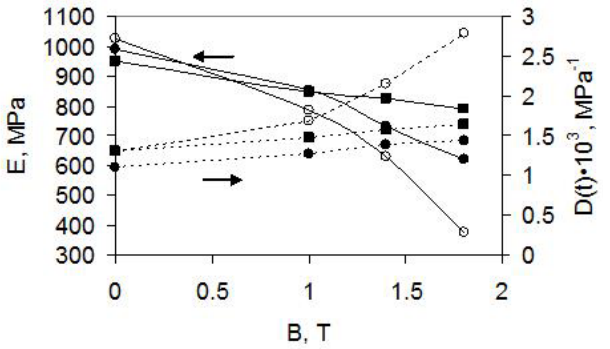

Fig. 3 Dependence of instantaneous total creep compliance D(t) and elastic modulus E after the creep tests for 10 minutes for unirradiated (o) and irradiated with 100 kGy (●) and 150 kGy(■) specimens of HDPE.

It should be noted that the results of HDPE almost completely coincide with the results obtained in Ref. [16] where it was found that modulus of elasticity of polypropylene decreased 2.5 times at induction of B equal to 0.8 T, but the modulus of polyethylene terephthalate decreased 3 times.

The cross-linking of polyethylene by irradiation affects the mechanical behaviour of material properties in magnetic field, reducing the pseudo plasticity with increase of irradiation dose. The values of elastic modulus E for irradiated polyethylene at doses 100 and 150 kGy decrease only 1.6 and 1.2 times while D(t) has increased only 1.2 and 1.3 times. We can conclude that even at the dose of 100 kGy the effect of MF is reduced for about 2 times.

Kinetics of increase of deformation with time for composites with the content of EPDM 20wt% measured at a constant stress equal to 2.2 MPa is seen in Fig. 4. Similar character of dependence on increase of MF induction in comparison to entire polyethylene is seen in the curves of the total creep compliances. Achieved total deformations of entire unirradiated composite of HDPE 80/EPDM 20 are significantly increased after the time of loading under the influence of magnetic field in comparison to measured in the absence of MF as well as it was seen in case of entire HDPE. The values of creep compliances measured at 1.4 T and 1.8 T were 1.6 and 2.1 times greater in comparison to D (t) recorded in the absence of the field that is similar to entire polyethylene.

Improvement of these characteristics is seen in case of radiation modified specimens especially at the dose of 150 kGy in comparison to entire polyethylene (see the curves e and f in Fig. 4). It is contributed to increase of the amorphous phase of composite. As we know, cross-linking occurs predominantly in the amorphous region. Increase of the cross-linked parts more effectively minimizes the effect of MF on the creep in comparison to entire HDPE. This is clearly evident from approach of the curves each to other, seen in Fig. 2c. The value of D(t) at irradiation dose 150 kGy in a MF with induction 1.8 T was 40% less compared to the value of D(t) for unirradiated sample.

Dependence of instantaneous total creep compliance D(t) and elastic modulus E on induction of MF in the creep tests for unirradiated and irradiated specimens of HDPE 80/EPDM 20 is seen in Fig. 5.

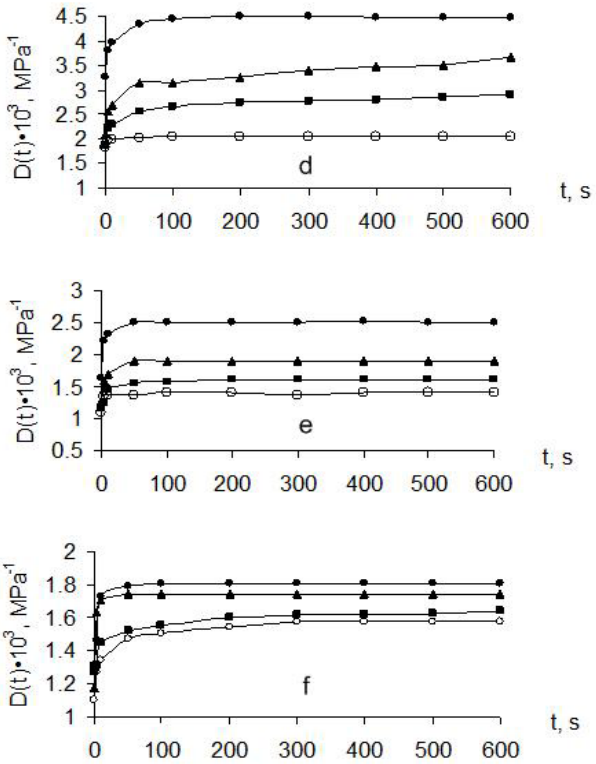

Fig. 4 Experimental curves of total creep compliance for (d) unirradiated and irradiated with (e) 100 kGy and (f) 150 kGy composite of HDPE 80%/EPDM 20% measured in the absence of magnetic field (o) and in a constant magnetic field with induction B equal to 1 (■), 1.4 (▲) and 1.8 T (●).

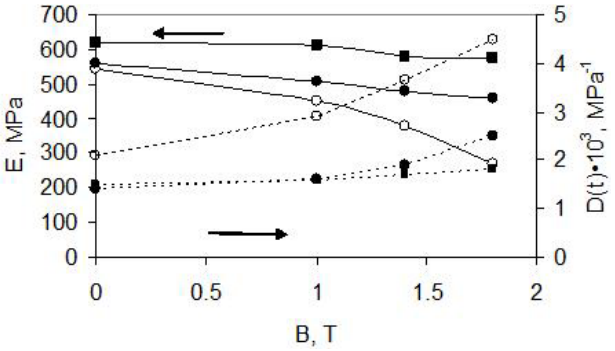

Fig. 5 Dependence of instantaneous total creep compliance D(t) and elastic modulus E after the creep tests for 10 minutes for unirradiated (o) and irradiated with 100 kGy (●) and 150 kGy(■) specimens of HDPE 80/EPDM20.

The calculated elastic modulus has noticeably decreased with increased induction while the values of D(t) tend to increase. For unirradiated sample elastic modulus decreases 2 times that is less than in case of entire HDPE that show an increased durability of HDPE 80/EPDM 20 in magnetic field in comparison to entire HDPE.

Increased effect of irradiation significantly affects the mechanical behaviour of material properties in magnetic field by reducing the pseudo plasticity with increase of irradiation dose (Fig. 5). The values of elastic modulus E for irradiated composite of HDPE 80/EPDM 20 at irradiation doses 100 and 150 kGy have decreased 1.2 and 1.1 times while the total creep compliance D(t) increased only 1.6 and 1.2 times.

It should also be noted that the irradiated samples showed a marked increase in stiffness in comparison to entire unirradiated. The elastic modulus E is increased by 14% and the total creep compliance D(t) reduced by 28% at absorbed dose equal to 150 kGy in comparison to unirradiated samples.

Kinetics of increase of deformation with time for composites with the content of EPDM 40wt% is seen in Fig. 6. It was measured at a constant stress equal to 2 MPa. Effect on the morphology of composite is seen from the curves attributed to practically equal content of both the components. Dependence of MF effect is highly affected by the elastic component in composite material.

The values of creep compliances measured at both the induction values of MF (1.4 and 1.8 T) were 1.6 times greater in comparison to D(t) recorded in the absence of the field. A reduced effect of magnetic field with increase of elastic component was confirmed.

Effect of the cross-linking attributed to changes in morphology of composite of radiation modified specimens is seen in Figs. 6h and 6i. It is clearly seen (Fig. 4) that the radiation modification of the samples effectively minimizes the effect of the magnetic field on the creep in comparison to unirradiated specimens. Meanwhile some of the plasticity may be attributed to the elastic nature of composite at the content of EPDM 40wt%.

Dependence of instantaneous total creep compliance D(t) and elastic modulus E on induction of magnetic field B for unirradiated and irradiated specimens of HDPE 60/EPDM 40 is seen in Fig. 7.

Increased effect of irradiation affects the mechanical behaviour of material properties in MF, almost totally reducing the effect of MF on the creep with increase of irradiation dose (Fig. 7). The values of elastic modulus E for irradiated composite of HDPE 60/EPDM 40 at irradiation doses 100 and 150 kGy decreased 0.95 and 0.9 times while the total creep compliance D(t) increased only 1.5 and 1.2 times in comparison to unirradiated specimens at B equal to 1.8 T.

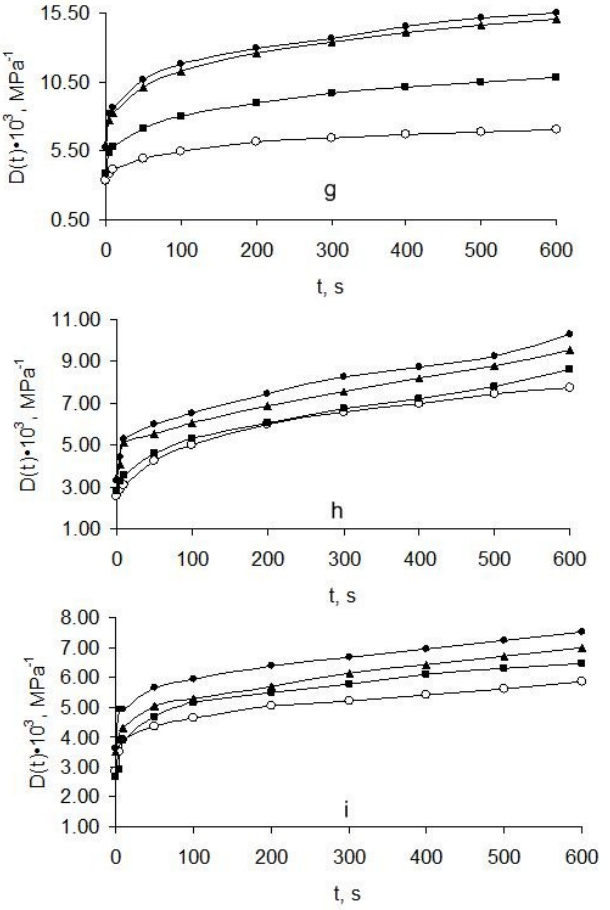

Fig. 6 Experimental curves of total creep compliance for (g) unirradiated and irradiated with (h) 100 kGy and (i) 150 kGy composite of HDPE 60%/EPDM 40% measured in the absence of magnetic field (o) and in a constant magnetic field with induction B equal to 1 (■), 1.4 (▲) and 1.8 T (●).

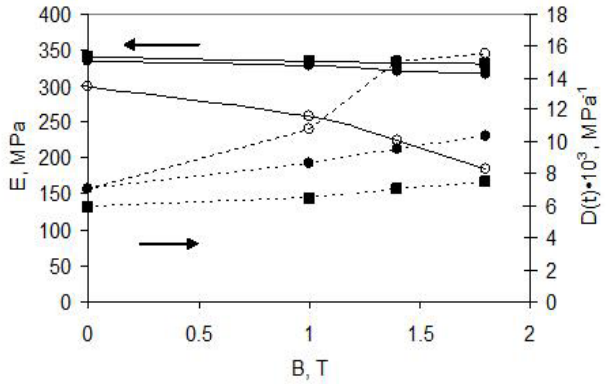

Fig. 7 Dependence of instantaneous total creep compliance D(t) and elastic modulus E after the creep tests for 10 minutes for unirradiated (o) and irradiated with 100 kGy (●) and 150 kGy (■) specimens of HDPE 60/EPDM40.

A marked increase in stiffness of irradiated composites is seen in comparison to unirradiated specimens. The elastic modulus E has increased by 2 times, and the total creep compliance D(t) has reduced by 2 times at absorbed dose equal to 150 kGy in comparison to unirradiated samples. It is remarkable that dependence of elastic modulus E(B) is completely linear at doses 100 and 150 kGy in comparison to unirradiated specimens.

The last investigated composite consisted mainly of elastomer with the content of HDPE 40wt% (Figs. 8 and 9). Kinetics of increase of deformation with time was measured at a constant stress of 1.9 MPa.

The values of creep compliances measured for unirradiated specimens at induction of 1.4 T and 1.8 T were only 1.1 to 1.2 times greater in comparison to D (t) recorded in the absence of the field. A reduced effect of magnetic field with increase of elastic component was confirmed.

Effect of the cross-linking attributed to changes in morphology of composite of radiation modified specimens is seen in Figs. 9k and 9m. It is clearly seen that irradiated specimens of HDPE 40/EPDM 60 have an increase of deformation at B > 1 T that may be attributed to some increased plasticity of vulcanized part of composite as the morphology is more affected by the elastomer than by the part of polyethylene. It is confirmed by the results discussed in Refs. [26-27].

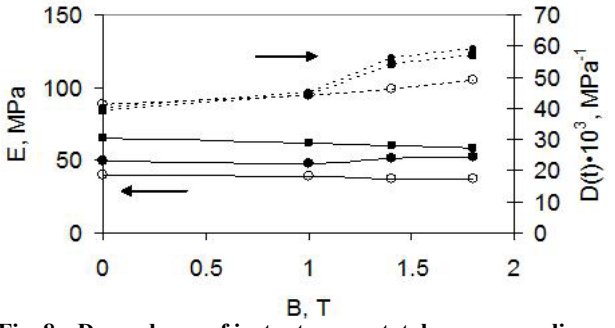

Fig. 8 Dependence of instantaneous total creep compliance D(t) and elastic modulus E after the creep tests for 10 minutes for unirradiated (o) and irradiated with 100 kGy (●) and 150 kGy (■) specimens of HDPE 40/EPDM60.

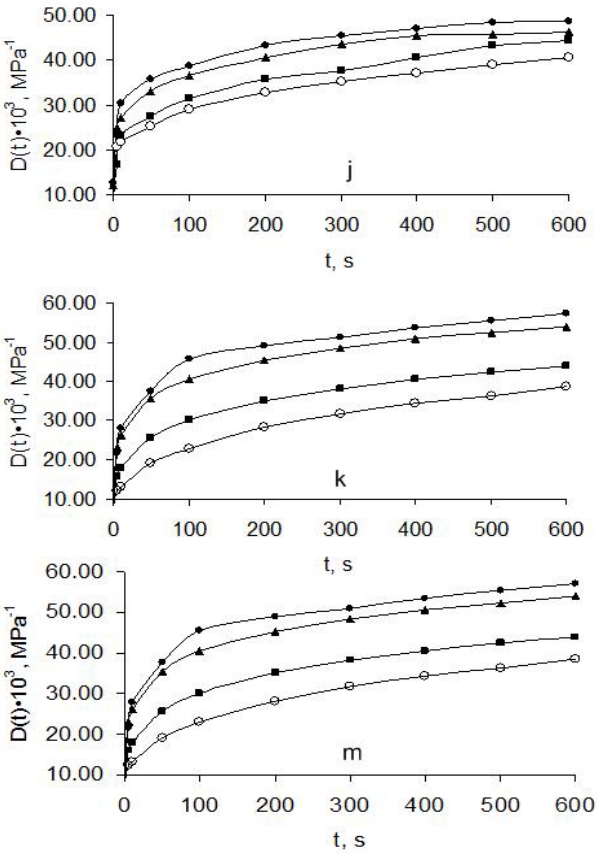

Fig. 9 Experimental curves of total creep compliance for (j) unirradiated and irradiated with (k) 100 kGy and (m) 150 kGy composite of HDPE 40%/EPDM 60% measured in the absence of magnetic field (o) and in a constant magnetic field with induction B equal to 1 (■), 1.4 (▲) and 1.8 T (●).

Almost totally decreased effect of magnetic field on unirradiated composite with the content of EPDM 60wt% (a relatively small changes of deformation and almost no changes of elastic modulus) confirmed the hypothesis that both the irradiation increase of the

content of elastomer reduces the undesired effect of pseudo plasticity of crystalline and semi crystalline polymers.

A marked increase in stiffness with increase of irradiation dose coincides with the theory of elastic forces that may be attributed to cross-linked parts in amorphous phase and the elastic character of EPDM. It is well seen from the changes of the total creep compliance D(t) that has increased 1.2 times at absorbed dose equal to 150 kGy in comparison to unirradiated samples at B equal to 1.8 T.

3.2 X-Ray Diffractometry Data Analysis

X-Ray diffractograms (XRD) for unirradiated and irradiated blends were used to see any possible changes in crystallinity of EPDM/HDPE blends with the content of HDPE 40-100wt% after the irradiation. Compatibility of both the materials, the semicrystalline HDPE and amorphous elastomer type EPDM, was determined. According to literature, the most significant reflection signals in diffraction curves of HDPE are visible in the area of 10°-40° in 2Θ scale, corresponding to peaks at 21.5°-21.6° (corresponds to diagonal crystalline plane 110), 23.9°-24.5° (corresponds to perpendicular crystalline plane 200), and the small peak at 36.07° [28-29].

The obtained X-ray diffraction curves were azimuthally integrated. The multiple peak data were resolved into individual peaks by a fitting procedure. The peaks were interpreted, by the Lorentz peak function as the best fitting [28]. Degree of crystallinity χ_c is calculated as the ratio of the total area under the crystalline peaks (the peaks of planes 110 and 200) to the full area-sum of the crystalline peaks and the broad peak of amorphous area as shown in Eq. (1).

$$\chi_c = \frac{I_{110} + I_{200}}{I_{110} + I_{200} + I_a} \quad (1)$$

I_{110}, I_{200} and I_a stand for integrals of the scattering intensities of the crystalline, amorphous peaks respectively. The calculated values are summarized in Table 1.

Table 1 Degree of crystallinity calculated from XRD.

HDPE (wt.%)	χ_c		
	0 kGy	100 kGy	150 kGy
100	0.58	0.62	0.63
80	0.51	0.46	0.45
60	0.44	0.40	0.38
40	0.27	0.19	0.19

Results show differences in estimated values of degree in crystallinity at various HDPE/EPDM ratios that correlate with the results obtained by deformation in tension at constant stresses. The observed changes in crystallinity are possibly related to cross-linking. Decrease in crystallinity can be explained by intermediate phase increase between the two polymers as the content of EPDM in composite increases. In case of polypropylene that has been explained by decrease of PP spherulites as the EPDM is mixed with PP [30]. That could be an explanation for changes in crystallinity of polyethylene with increase of the EPDM content in composite that is explainable in case of HDPE/EPDM composites.

The increase of irradiation dose causes chain scission processes as the high energy electron irradiation affects the radical reactions. Accumulation of excitons can contribute to chain scission processes, giving rise to the final number of chains in the absence of chain, which is related to the exciton energy release. As a result of radiation defects of the crystalline phases are “excluded” to the lamella boundary between crystalline and amorphous phases and getting rid of energy defect reactions may begin to form cross-linked sites. It could promote the expansion of the phase boundary as a result of increased entropy in amorphous phase.

3.3 DTA Diffractometry Data Analysis

The DTA thermograms of unirradiated and irradiated with 150 kGy HDPE/EPDM composites are seen in Fig. 10 (decrease of the black shape of curves indicating increase in the content of EPDM). From the DTA endothermic peak maximums it is seen that increase in the content of EPDM shifts the melting peaks

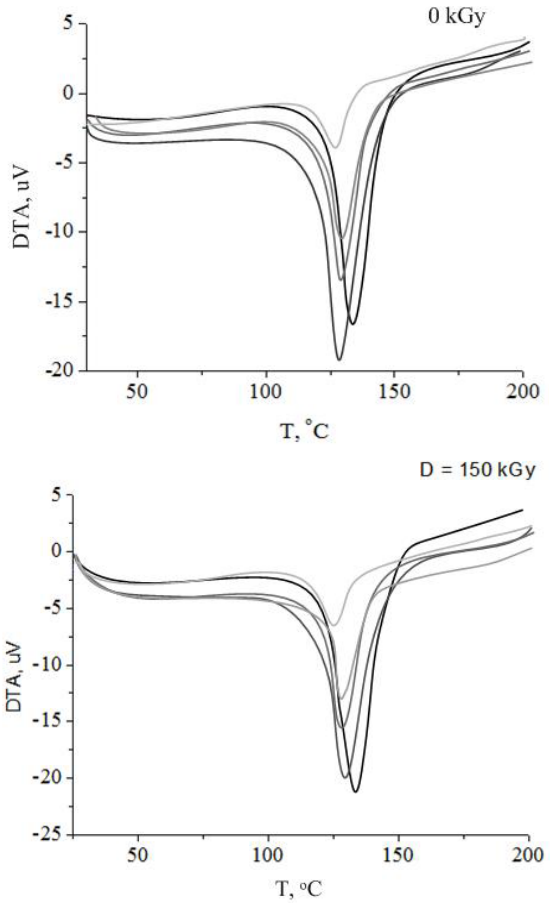

Fig. 10 DTA curves of unirradiated and irradiated up to absorbed irradiation dose 150 kGy EPDM/HDPE specimens.

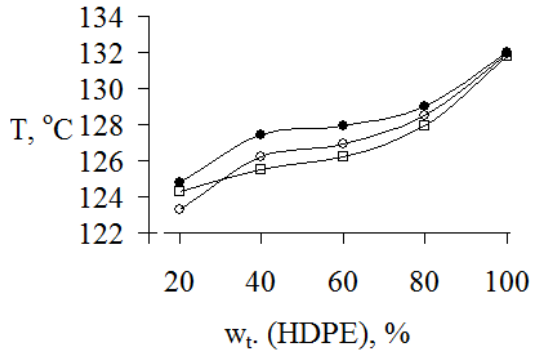

Fig. 11 Melting temperatures of unirradiated and irradiated up to absorbed irradiation doses 100 kGy and 150 kGy EPDM/HDPE composites.

towards lower temperatures that testify interaction between the polyethylene and the EPDM terpolymer. Narrowing of the curves and decrease of the shift for irradiated specimens indicate effect of cross-linking on compatibility of both the components.

The calculated melting temperatures at the maximum of melting peaks for both the irradiation doses are seen in Fig. 11. The results show that melting temperatures are decreased for irradiated composites in comparison to unmodified ones. That could testify the processes discussed about the changes in crystallinity that are explained by increase of amorphous phase and reduced mobility of HDPE macromolecules in intermediate phase of both the components.

4. Conclusions

The main objective of this work was to investigate the influence of constant magnetic field on the deformation properties (changes of modulus of elasticity elastic properties and the creep in tension) of unirradiated and radiation cross-linked HDPE/EPDM composite materials at a wide ratio of both the components.

The main task was to investigate and decrease possible pseudo plasticity as effect of magnetic field interaction to polymer materials during the tension under the action of magnetic field. It is necessary to control the deformation properties of structural, insulation and coating materials used in long term load in high intensity magnetic field (> 1 T).

It is stablished that exposure to magnetic fields causes a marked decrease in the modulus of elasticity of the unirradiated materials. We also identified a significant effect of the magnetic field on the creep of unirradiated polyethylene. Decrease of elastic modulus for 3 times was investigated at high magnetic field with induction equal to 1.8 T. It was concluded that increase of the content of elastomer together with irradiation with accelerated electrons of a relatively small absorbed irradiation doses (100 and 150 kGy) can effectively minimize the effect of the magnetic field on the creep of the material. There is great advantage to regulate (increase or decrease) the pseudo plasticity of binary composites of semi crystalline polymers and elastomers by changing the content of elastomer and the irradiation dose. The results make it possible to

adjust these polymer materials as coating and insulation materials in areas under the tension in high magnetic fields with induction of the field in the range of 1.0-1.8 T. Many construction materials of thermo nuclear reactors (ITER, DEMO and other reactors with tokamak) based on polymer composites can be attributed to such materials.

The XRD and DTA data have demonstrated changes in interaction between the semicrystaline high density polyethylene and ethylene propylene diene. That is explained with increase of interphase of both the components. Increase of the cross-linked moieties allow to decrease pseudo plasticity that is undesired process for construction materials applied in tension for nuclear applications were enriched durability of materials and safety is necessary.

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