

“MEMORY EFFECT” INDUCED ON THERMOPLASTIC MATERIALS BY CROSS LINKING WITH ACCELERATED ELECTRON BEAM

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ABSTRACT

The present report shows the results of the investigations concerning the obtaining of “memory effect” as a result of internal structure change of thermoplastic materials by cross linking with electron beam produced by an electron accelerator and a complex device for the product displacement. The effect consists in the returning at the original form of these materials, when they are heated at temperatures closed at that of vitrification.

Electron beam cross-linking leads not only at the memory effect but also at the improvement of mechanical properties, thermal stability, as well as the resistance at different chemical agents of the material.

KEY WORDS: irradiation, cross-linking, memory effect, expanded state, heat-shrinkage, heat shrinkable tubes.

1. INTRODUCTION

Heat shrinkable tubes are the most used products made of polymeric materials and especially of compounds based on polyethylene, which as a result of **cross linking** by accelerated electron beam followed by **expansion – change of shape** - at a ratio (D/d) till 2,5, obtain the shrinking characteristic when they are heat on any object with dimensions till the initial diameter (d) – **heat shrinkage**. After cross linkage, heat shrinkable tubes are expanded. An electron beam produced by an electron accelerator and using a complex device makes cross-linking. Cross-linking means the formation of new bonds between the neighbored polymeric chains and a three dimensional mesh is made. Cross-linking induces elastomeric characteristics to the polymeric material [1,2]. **Heat shrinkable tube expansion** consists in a uniform heating of whole tube surface in special ovens at 130⁰C, after that the tube increases its diameter at the final dimension by means of different processes, in a cooling mould.

2. CROSS-LINKING BY ELECTRON BEAM

Cross-linking consists of the chemical bonds between the hydrocarbon chains (fig. 1). “Memory effect”, effect that governs the

property of these materials to return at their initial form when they are heated at a temperature nearly that of vitrification, after a previously expansion, is the result of the structural change occurred of these polymeric materials.

For industrial irradiation one uses sources of γ radiation and electron accelerators. The electron accelerators are more useful because their higher irradiation dose flow.

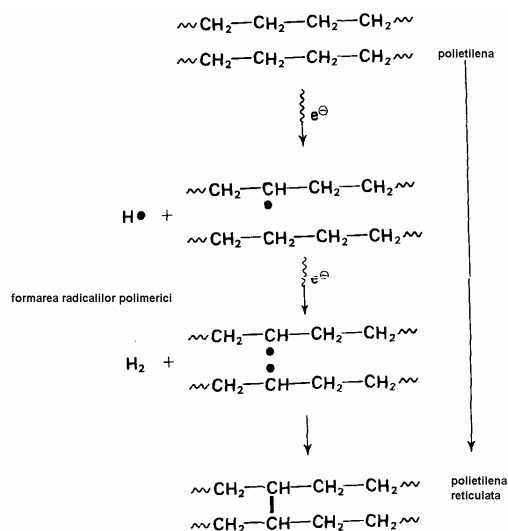


Fig. 1. Polyethylene cross-linking using electron beam.

Also, even the spend of energy is higher at the electron beam irradiation, the devices based on radioisotope are 3÷5 times more expensive than the accelerators, and the unit cost of irradiation is double. Electrons must have the energy of 5MeV in view to induce a chemical reaction. The main accelerated electron beam parameters with interest for the industrial irradiation process are: electron beam energy 1÷5MeV and power beam 20÷50kW. The study of the influence of dose flow on cross-linking degree shows that the influence of the first is not so considered on the cross-linking efficiency, at a total dose of 8Mrad, obtained with a dose flow placed in the 0,1÷3,5Mrad domain. Figure 2 shows that cross-linking degree, as function of gel fraction, depends on the total dose only and doesn't depend on flow dose received by the polymer sample.

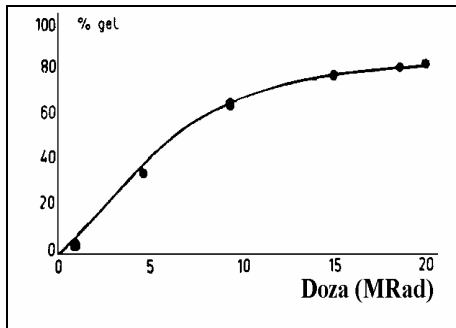


Fig. 2. Cross-linking degree as function of dose.

The size and the homogeneity of dose decide the size and the homogeneity of cross-linking degree, which decide some technical properties of heat shrinkable tubes. Figure 3 shows the dependence of return ratio (*R*) on the cross-linking degree of the sample expanded at 2,5:1 ratio. The cross-linking was calculated by the orto-xylene extraction method. In this picture one can observe that the heat shrinkable tubes memory effect is affected by the polymer cross-linking. Thus, samples non-irradiated have the return ratio only 23%, while samples with 50% cross-linking degree have 100% return ratio. The cross-linking process involves both the electron accelerator and the equipment for irradiation of heat shrinkable tubes that must make safe the motion and the rotation of tubes in front of accelerated

electron beam, using different methods in view to assure a homogenous irradiation.

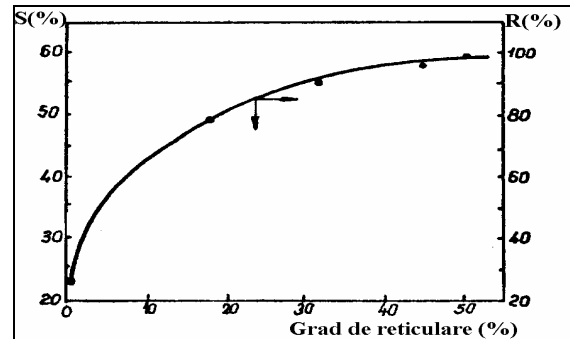


Fig. 3. Cross-linking degree function of return ratio.

There are many methods of transport of tubes under the electron beam and we note the most known: **many-eight method** (that involves the irradiation of tubes with diameter in less than 14mm), **rotation and translation method** (that involves the irradiation of tubes with diameter in less than 14mm), **rotation of all tubes without rotation of each of one in the irradiation diaphragm zone** (that involves the irradiation of tubes with diameter of 5÷50mm but it generates many wastes because of the non uniformity of the dose) and the **method of rotation of each tube irradiated at different doses, controlled by the number of transit behind the electron beam, with 360° in the diaphragm zone** in the same time with its own axe rotation which puts out the disadvantages generated by the other methods.

3. IRRADIATION EQUIPMENT

Irradiation equipment and the method of rotation of **each tube irradiated at different doses, controlled by the number of transit behind the electron beam, with 360° in the diaphragm zone** is a national newness and is the object of the Brevet of Invention no. 115499 dated on 30.03.2000. There are companies all over the world, like RAYCHEM, ELCOM Italy, Institute of Radiation Chemistry Warsaw, VSZM Budapest, which have realized their irradiation equipment, and have obtained low cost by increasing productivity and quality of heat shrinkable tubes.



Fig. 4. Complex equipment for irradiation with electron beam of heat shrinkable tubes.

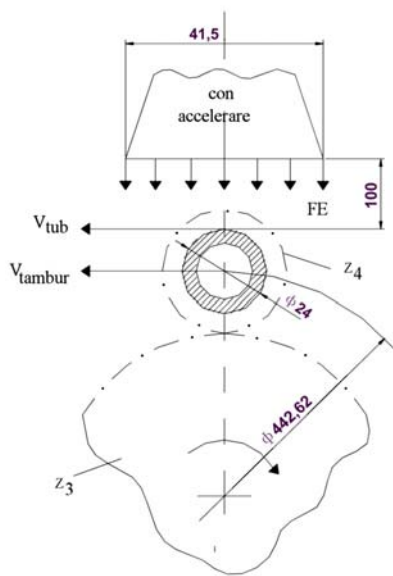


Fig. 5. The position of tube during the irradiation with electron beam.

The internal diameters of heat shrinkable tubes, irradiated with this equipment, are between 5 and 50mm, wall thickness between 1.5 and 2mm and length is 1200mm. The main technical characteristics of the equipment are: gauge dimensions (l x L x h): 900 x 2390 x 694mm; Heat shrinkable material: low density polyethylene for electrical use type K 322, NI 4756/71 Mich; Maximum heat shrinkable tube length: 1000÷1200mm; internal diameter of heat shrinkable tube intended for irradiation 5÷50mm; maximum number of tubes

irradiated in the same time: 27 pieces; voltage: 220V±10%; weight: 380kg; current input: 7,5kW.

4. NEWSNESS AND ADVANTAGES OF THE IRRADIATION EQUIPMENT

The complex irradiation equipment for heat shrinkable tubes uses as newness the **original method of rotation of all tubes, irradiated at different controlled doses, by the number of transit behind the electron beam, and the rotation of each tube with 360° in the diaphragm zone.**

In comparison with the other methods this one has the followed advantages: high productivity, high productivity: 27÷32 tubes per irradiation; irradiation of tubes with long length (1000÷1200mm); there are not wastes; uniformity of irradiation doses on tube surface; uniformity of wall of tube after the expansion; uniformity of mechanical and electrical characteristics of tubes; medium price.

The newness elements of this equipment are:

- The rotation of all tubes (27 pieces) in front of the electron beam with a changeable speed, depending on the irradiation dose;
- The continue rotation of each tube around its own axis with 360°C in front of the diaphragm (41,5mm width) of accelerating cone, unconcerned with the rotation of all tubes;

- The quick catch of tubes on support sticks by cones and their quick joining on the equipment;
- The achievement of a chain wheel with a high diameter by a bandage with gall chain ($p=6\text{mm}$) to gear to move at the same time of all the 27 chain wheels;
- The electric operating and rotation adjustment by an electric block fixed on a tripod outside the irradiation room;
- The checking of the irradiation process of heat shrinkable tubes from a checkroom by a closed TV network.

This complex equipment is a modern one, with high productivity, using removable parts or component parts and little movable number of pieces. This is the reason for which this equipment has a high reliability coefficient.

5. WHERE AND WHAT FOR ARE USEFUL HEAT SHRINKABLE TUBES

Because their high performances: physical, chemical and electrical properties, chemical and thermal stability, these tubes are used in energetic field as joint sleeves both for installation and repairing power cables, internal or external terminals, repairing of cable insulation, different marks, protection against corrosion, etc.

Beside the high performances of heat shrinkable products, the use of this new technology shows some advantages such are: safe use, low time to put in use, long life in use compared with the low cost price.

Because their excellent properties the heat shrinkable tubes are used in many activity fields: communication, power techniques, electric technologies, cars manufacturing, aircraft and agriculture.

As regards their manner of acting against the fire, heat shrinkable tubes are made in flame retarded and not flame retarded material.

6. CONCLUSIONS

a. The investigations concerning the obtainment of “memory effect” as a result of internal structure change of thermoplastic materials by cross linking with electron beam produced by an electron accelerator and a complex device for the product displacement, are very important for the obtaining of heat shrinkable products, especially tubes, in our economy.

b. The equipment is a national newness based on original method of the author of this paper, of rotation of each tube irradiated at different doses, controlled by the number of transit behind the electron beam, with 360° in the diaphragm zone in the same time with its own axe rotation.

c. This method eliminates the disadvantages generated by the other methods, especially that of wastes, ensuring an uniform dose and an uniform “memory effect” on the surface of the material, which lead at an uniform appearance of the wall of tub after the expanding process, a good quality, a high productivity and a lower price of heat shrinkable tubes asked for them, on market.

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