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IMPROVEMENT OF POLYPROPYLENE PROPERTIES

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Abstract: *Radiation processing involves the use of natural or man-made sources of high energy radiation on an industrial scale. The principle of the radiation processing is the ability of the high energy radiation to produce reactive cations, anions, and free radicals in materials. The industrial application of the radiation processing of plastic and composites includes polymerization, cross-linking, degradation and grafting. Radiation processing involves mainly the use of either electron beams from electron accelerators or gamma radiation from Cobalt-60 sources. Radiation processing does not make the product radioactive. The majority of industrial applications of radiation processing are a cross-linking of wire and cable insulations. A comparison of the mechanical and thermal properties of natural and irradiated polypropylene (unfilled and filled – 25% GF) is presented in this article.*

Key words: *Polymer, Irradiation, Crosslinking, Mechanical Properties*

1. INTRODUCTION

The electron accelerator operates on the principle of the Braun tube, where a hot cathode is heated in vacuum to such a degree that electrons are released.

Simultaneously, high voltage is generated in a pressure vessel filled with insulating gas. The released electrons are accelerated in this vessel and made to fan out by means of a magnetic field, giving rise to a radiation field. The accelerated electrons emerge via a window (Titanium foil which occludes the vacuum) and are projected onto the product.

Cobalt 60 serves as the source of radiation in the gamma radiation plant. Many of these radiation sources are arranged in a frame in such a way that the radiation field is as uniform as possible. The palleted products are conveyed trough the radiation field. The radiation dose is applied gradually, that is to say, in several stages, whereby the palleted products are conveyed around the Co – 60 radiation sources several times. This process also permits the application of different radiation doses from one product type to another. It can be used for irradiation of polyolefines, polyesters, halogen polymer and polyamids from thermoplastics group, elastomers and thermoplastic elastomers. Some of them need the addition of crosslinking agent. The dimensional stability, strength, chemical resistance and wear of polymers can be improved by irradiation [2]. Irradiation cross-linking normally creates higher strength as well as reduced creep under load if the application temperature is above the glass transition temperature (T_g) and below the former melting point. Irradiation cross-linking leads to a huge improvement in resistance to most of the chemicals and it often leads to the improvement of the wear behaviour.

The thermoplastics which are used for production of various types of products have very different properties. The main group presents standard polymers which are easy obtainable with favourable price conditions [3]. Limited level of both mechanical and thermal properties is big disadvantage of standard polymers. The group of standard polymers is the most considerable one and its share in the production of all polymers is as high as 90%.

The engineering polymers are a very important group of polymers which offers much better properties in comparison to standard polymers. Both mechanical and thermal properties are much better than in case of standard polymers. The production of these types of polymers takes less than 10 %.

High performance polymers have the best mechanical and thermal properties but the share in production and use of all polymers is less than 1%.

Still, it is necessary to say that in the decision-making process (which kind of polymers will be used) the application area and price are important. The differences in price are exorbitant – from unit Euros (standard polymers) to tens or hundred Euros per kg in case of some types of high performance polymers.

In connection with these data we have to ask if it is necessary to use engineering polymers or even high performance polymers in some application. In many cases it would be possible to use standard or engineering polymers and to improve their properties, e.g. by irradiation.

Due to electron accelerators, the required dose can be applied within seconds, whereas several hours are required in the gamma radiation plant.

The principle of irradiation using Gamma and Electron rays and the ability of penetrating the irradiated material are given in the Figure 1.

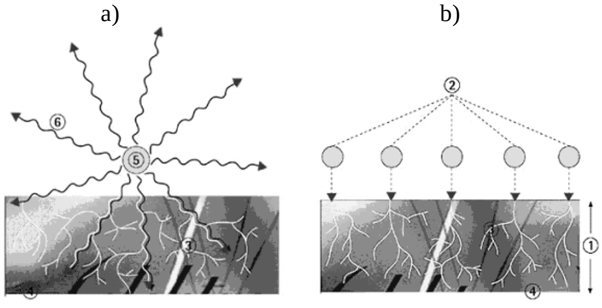

Fig. 1. Design of Gamma rays (a) and Electron rays (b)
a) 3 – secondary electrons, 4 – irradiated material,
5 – encapsulated Co – 60 radiation source, 6 – Gamma rays
b) 1 – penetration depth of electron, 2 – primary electron,
3 – secondary electron, 4 – irradiated material

2. EXPERIMENT

The properties of natural (not irradiated) and irradiated polypropylene (PP), both unfilled and filled with 25% of glass fibres, have been compared. The injection moulding machine DEMAG – EGROTECH 50 – 200 has been used for sample preparation. Irradiation was carried out in the company BGS Beta Gamma Service GmbH & Co, KG, Saal am Donau, Germany ith the electron rays, electron energy 10MeV, doses minimum of 15 and 33 kGy.

The following tests with the use of stated equipment has been carried out: Tensile test, Bend test, Impact test, DMA test, TMA test, REM test.

3. RESULTS AND DISCUSSION

The cross-linking irradiation increased the tensile strength Rm and modulus E by more than 22% in case of PP and by 15 to 20% in case of PP 25 GF (Figure 2, 3). The changes of flexural strength lay between 28% and 40% in case of PP and between 15 % and 17% in PP 25 GF. The doses of irradiation have only small influence on tensile and flexural properties of both PP and PP 25 GF.

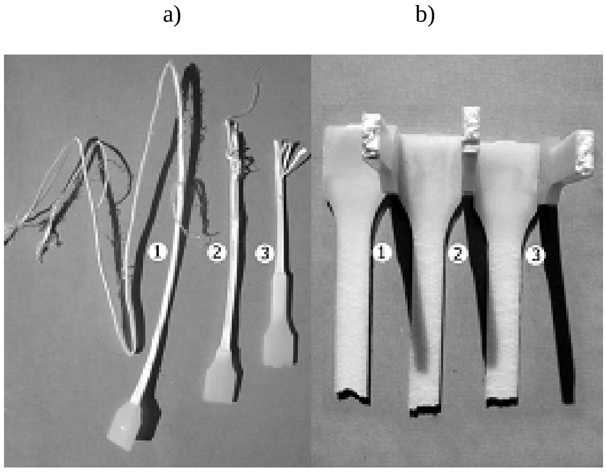

Fig.2. Specimens after Tensile test
a) unfilled PP, b) filled PP
1 – 0kGy, 2 – 15kGy, 3 – 33kGy

The changes in dynamical – mechanical properties have been found out. The values of Complex modulus E^* are improved on the whole temperature scale. There is no influence of applied doses of irradiation on the E^*.

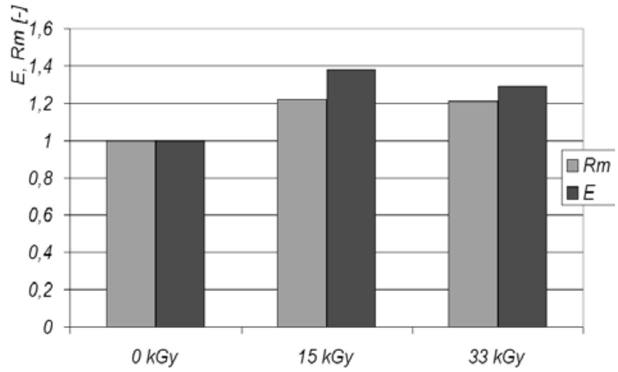

Fig. 3. Tensile strength and E – modulus of PP

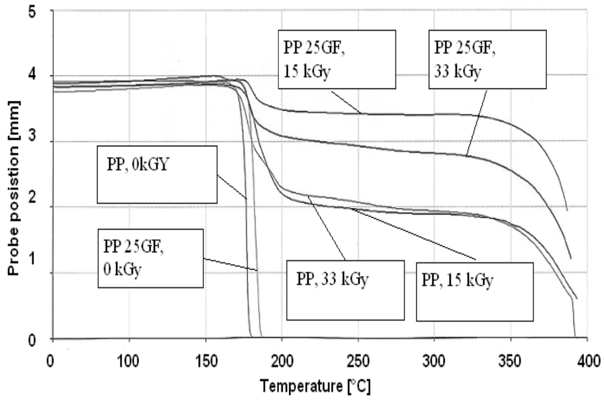

Fig. 4. Results of thermal analysis of filled and unfilled of PP

Very important changes in thermal stability after irradiation have been found (Figure 4). The thermal stability is much better even by temperature higher than its former melting point. The adhesion of polymer to reinforcement is significantly improved by irradiation.

4. CONCLUSION

The differences of mechanical and thermal properties of irradiated and natural PP have been found out. From the practical point of view the most important is the enormous improvement of the thermal stability of irradiated PP. Important details:

- Irradiation will be carried out on the final parts, for example injection moulded parts, extruded or thermoformed products.
- The product after irradiation is not radioactive
- The irradiation is an additional process which is not free of charge.

Irradiation needs additional costs. It is necessary to take in account all the benefits resulting from the irradiation process already during the design stage of the plastic product.

5. ACKNOWLEDGEMENTS

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