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SURFACE PROPERTIES OF ELECTRON IRRADIATED POLYAMIDE 6,6

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ABSTRACT

Hardness and wear properties of the electron irradiated polyamide 6,6 were evaluated under electron beam irradiation. Samples of polyamide 6,6 without additives, for the mechanical tests were injection-molded. These samples were irradiated with electrons at a dose rate of 2.42 kGy/s and the doses were 70, 100, 150, and 200 kGy. Three sets of samples were analyzed. One set of non-irradiated and irradiated specimens and two other sets with non-irradiated and irradiated samples that were immersed, during six months, in petroleum and sea water separately were studied in order to evaluate the crazing effect produced by these liquids. The experimental results have shown that the ionizing radiation, in the range from 70 to 200 kGy, increases the hardness resistance and reduces strongly the abrasion loss. The crazing effect produced by seawater and petroleum was mainly observed on the non-irradiated samples and also that seawater was more aggressive than petroleum on the surface structure of polyamide 6,6. Additionally, over a dose of 70 kGy, the crazing effect of both liquids was completely eliminated.

1. INTRODUCTION

Radiation Processing has been applied to improve product quality, energy saving and to manufacture products with special properties as a result of inducing reactions in solid state at room temperature [1]. This radiation processing brings, many advantages comparing to the conventional chemical processing [2,3]. Polyamide 6,6 due to its excellent mechanical, thermal and electrical properties and its great performance in multiple industrial applications is considered one of the most important engineering polymer [4]. However, in specific applications, some of its properties need to be improved by means of additives or fillers to reach the required properties, which also increase its final cost. By these considerations, the aim of this work was to apply the ionizing radiation to improve the natural mechanical properties of polyamide 6,6. Also, to evaluate the irradiation parameters, and the mechanical performance of the irradiated polymer in order to use the cross-linking, induced by ionizing radiation, as substitute of additives and fillers.

Polymer areas exposed to certain liquids will craze that is the development of small surface cracks affecting the surface mechanical properties of the material [5]. Crazing occurs only when the parts of polymer, exposed to liquids, are under stress, produced either by design or from residual stresses locked in during fabrication (molding or injection).

2. EXPERIMENTAL

The material used in this work was polyamide 6,6 without additives. Samples for the mechanical tests were injection-molded using a Battenfeld injector. These samples were irradiated with electrons at the CTR- IPEN irradiation facilities, using a Dynamitron JOB 188 electron accelerator with 1.5 MeV and 37.5 kW, and the overall doses were 70, 100, 150, and 200kGy. These irradiated samples were conditioned at 23°C and 50% humidity for 40 hours before being mechanically tested. The hardness and wear measurements were performed, in air and at room temperature, according to the standards ASTM D-2240 [6] and ASTM D 1242 [7] respectively. The hardness Shore D was measured with a Zwick equipment using a load of 1kgf for 10 seconds, and the wear measurements were carried out using an abrasion tip with a load of 250g for 3 hours. All measurements were made in air and at room temperature. Hardness and wear measurements were used to evaluate the crazing effect on two sets of samples that were immersed, during 6 months, in petroleum and seawater, respectively. The immersion time of 6 month was required to reach the maximum of the crazing effect.

3. RESULTS AND DISCUSSION

The results and behavior of the hardness and wear measurements as a function of dose, are presented graphically in Figures 1, 2 and 3.

In Figure 1, for the first set of samples, hardness shore D values increase 13%, in the doses range between 70 to 100 kGy as compared with the values of non-irradiated samples.Beside that, from 100 kGy up to 200kGy the shore D value remain stable at about 90. The increase of the cross-linking density reaches its maximum value at about 120 kGy [2] and it is at this dose that the hardness also reaches its maximum value, remaining constant up to 200 kGy. On the other hand, the abrasion loss had shown a strong reduction of 20 times in the doses range between 70 to 200 kGy as compared with the values of non-irradiated samples. This was one of the most important results produced by irradiation.

The crazing effect was observed mainly on non-irradiated samples. It was also observed that seawater was more aggressive than petroleum on the surface structure of polyamide 6,6. In Figure 2, the seawater produces a reduction of 15 % and petroleum only 2.5 % in the hardness values for non-irradiated and non-immersed samples. It was also determined that the crazing effect, produced by both liquids, was reduced to almost zero on those samples that were irradiated with 70 kGy. In Figure 3, are presented the abrasion loss behavior produced by the crazing effect of seawater and petroleum. In wear measurements, polyamide in petroleum has shown no variations of its abrasion loss behavior in comparison with those samples that were not immersed in petroleum. On the other hand, seawater presents a decrease in the abrasion resistance of 17 % as compared with those samples that were not immersed in seawater. From 70 to 200 kGy the wear behavior, of both liquids, remain similar to those samples that were not immersed either in seawater or petroleum.

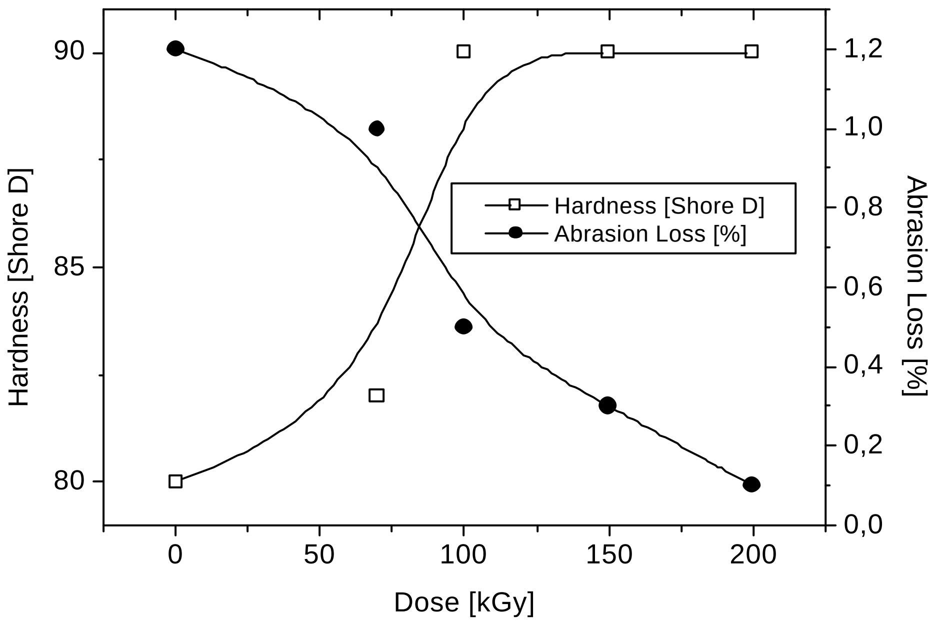

Figure 1. Hardness and abrasion loss of irradiated and non-irradiated polyamine 6,6.

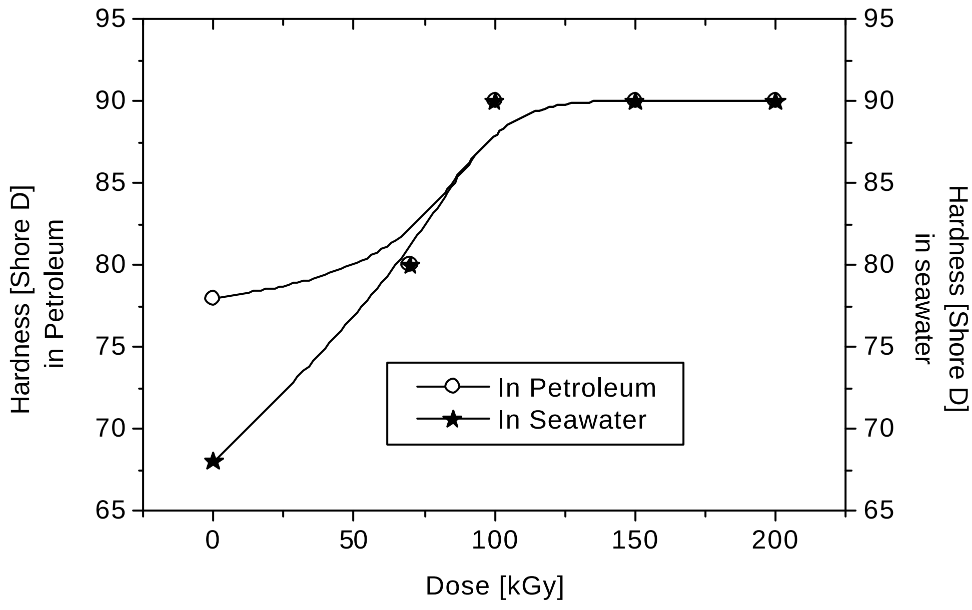

Figure 2. Seawater and petroleum crazing effect on hardness properties of Polyamide 6,6.

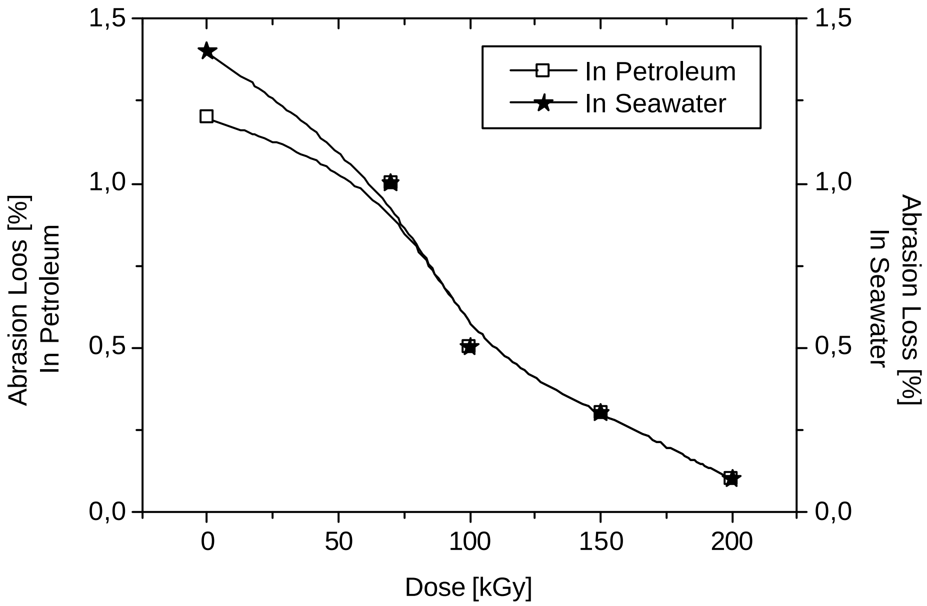

Figure 3. Seawater and petroleum crazing effect on wear properties of polyamide 6,6.

3. CONCLUSIONS

The experimental results of this work have shown that the ionizing radiation in the doses range from 70 to 200 kGy improves the hardness and resistance to abrasion of the irradiated polyamide 6,6.

The crazing effect of seawater and petroleum was observed on non-irradiated samples. It was also observed that seawater was more aggressive than petroleum on the surface structure of polyamide 6,6. Furthermore, over a radiation dose of 70 kGy, the crazing effect of both liquids was completely eliminated.

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REFERENCES

1. K.UENO, "The Radiation Cross-linking Process and New Products", *Radiat. Phys. Chem.*, **35**, pp. 126-131(1990).

2. S. MACHI, "New Trends of Radiation Processing Applications", *Radiat. Phys.Chem.*, **47**, pp. 333-336 (1996).
3. Y. TABATA, "Fundamentals of Radiation Chemistry", *Radiat. Phys. Chem.*, **18**, pp. 43-58 (1981).
4. R.J. WELGOS, " *Polyamides, Plastics*", Encyclopedia of Polymers Science and Engineering, Vol. 11 (KROSCHWITZ, J.I, Executive Editor), Wiley & Sons, New York (1990).
5. R.P. KAMBOUR, "*Crazing*", Encyclopedia of Polymers Science and Engineering, Vol. 4 (KROSCHWITZ, J.I., Executive Editor), Wiley & Sons, New York (1990).
6 AMERICAN STANDARD FOR TESTING MATERIALS. Standard Test Methods for Hardness of Plastics. ASTM D-2240
7 AMERICAN STANDARD FOR TESTING MATERIALS. Resistance of Plastics Materials to Abrasion. ASTM D-1242