Conference Proceedings of the Academy of Romanian Scientists
PRODUCTICA Scientific Session
ISSN 2067-9564 Volume **15**, Number **1**/**2023**

RADIATION PROCESSING OF PLASTICS FOR THE AUTOMOTIVE INDUSTRY

Ion Bogdan LUNGU[1]

Rezumat. *Industria automotive este o industrie extrem de tehnică, competitivă, inovatoare și sensibila la schimbari, care trebuie să producă vehicule sigure, acceptabile din punct de vedere al mediului și rentabile. Noile tehnologii schimbă modul în care mașinile sunt proiectate, dezvoltate și produse. Utilizarea plasticului a fost în continuă creștere datorită greutatii reduse, costului relativ scăzut, simplitatii producției, tehnologiilor care fabrica produse de înaltă performanță etc. Procesarea cu radiații a materialelor plastice a fost folosită de mai bine de 30 de ani pentru reticulare, grafting și compatibilizare. Radiațiile gamma le îmbunătățesc proprietățile mecanice, termice, chimice, izolatoare electrice și de mediu, ceea ce le găsește potrivite pentru aplicații de înaltă performanță, de exemplu, spațiu, automobile, construcții, nucleare și aplicații de apărare. Majoritatea materialelor plastice utilizate în mașini pot fi prelucrate cu radiații pentru a le crește caracteristicile necesare, cum ar fi rezistența la căldură, substanțe chimice și/sau rezistența.*

Abstract. *The automotive industry is a highly technical, competitive, innovative and change sensitive industry which has to produce safe, environmentally acceptable and cost effective vehicles. New technologies change the way cars are being designed, developed and produced. The use of plastic has been constantly encresing due to its lightness, relatively low cost, ease of production, technologies that produce high-performance products etc. Radiation processing of plastics has been used more than 30 years for crosslinking, grafting and compatibilization. The gamma irradiation enhance their mechanical, thermal, chemical, electrical insulation, and environmental properties, which finds them suitable for high performance applications, e.g., space, automobile, constructions, nuclear, and defense applications. Most of the plastics used in cars can be processed with radiation in order to increase their required characteristics like resistance to heat, chemicals and/or strength.*

Keywords: plastics, radiation processing, automotive

1. Introduction

The automotive industry is the third most important consuming sector of polymers after packaging and building & construction. Therefore, changes in the material usage can have major implications on polymer demand and the financial performance of polymer producers [1]. Five main areas of research and development according to Clepa Horizon 2020 are: 1. Decarbonisation of road transport, including advanced ICE power-trains; Electrification: Hybrids, Energy managment, Battery technology, alternative fuels 2. Advanced lightweight

[1]Eng., PhD, IRASM, "Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering" Institute, Magurele, Romania, (ion.lungu@nipne.ro).

materials: Materials and joints, New vehicle concepts and structures; 3. Safety: advanced driver assistance, platooning, full automated driving; 4. Intelligent transport systems; 5. Advanced Manufacturing-engineering technologies [2].

A modern car is made out of 5000 to 10000 components i.e. 30000 to 50000 individual parts, out of which 1/3 are made of plastic. In total, about 39 different types of basic plastics and polymers are used to make an automobile. In fig. 1 it is shown the plastic components and their placement in a modern car [1].

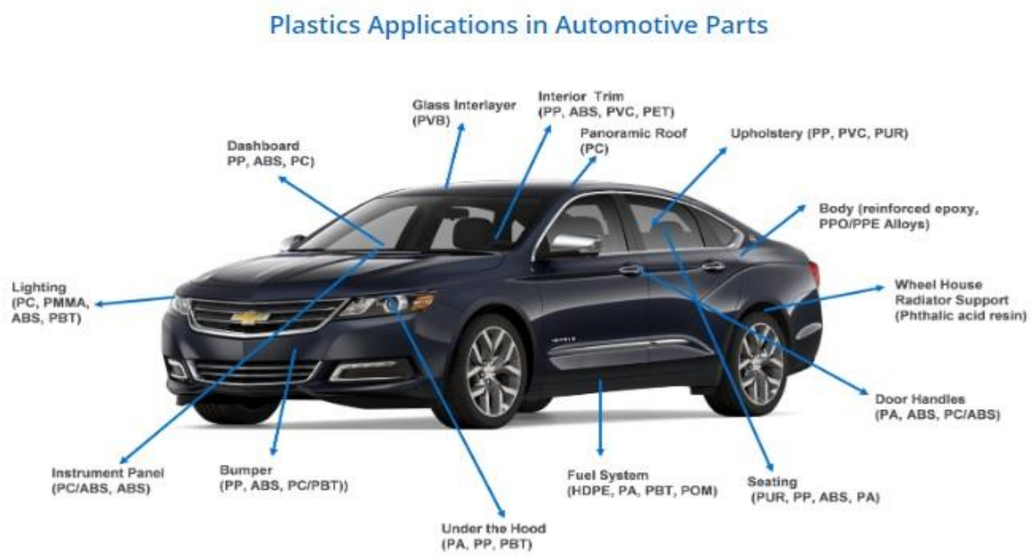

Fig. 1. Type of plastics and their placemenet in a car

More than 70% of the plastic used in automobiles comes from four polymers: polypropylene, polyurethane, polyamides and PVC. Plastic has become one of the key materials required for the structure, performance, and safety of automobiles in recent years, with growth in plastic consumption being driven by light weighting trends for fuel efficiency and consequently lower greenhouse gas emissions [3].

Radiation processing of plastics has been used more than 30 years for structural modification, polymerization, grafting, sterilization, and crosslinking of various thermoplastics and elastomers [4]. Most of the plastics used in cars can be processed with radiation in order to increase their required characteristics like resistance to heat, chemicals and/or strength and comply with environmental properties. Nevertheless, radiation processing of plastics makes them suitable for high performance applications, e.g., space, automobile, constructions, nuclear, and defense applications [5]. The most popular techniques use electron beam, γ radiation and last X-Ray. Electron beam treatment is a commercial alternative to gamma technology, but differs in some characteristics, allowing a higher and adjustable dose rate, small depth of radiation penetration into the material and it uses electricity. Gamma irradiation has a relative constant and small dose rate depending on the activity of the radioactive material, a high penetration rate and uses radioactive material. X-Ray is comparable to γ technology, the difference being that it is generated by electrical current and not radioactive sources [6].

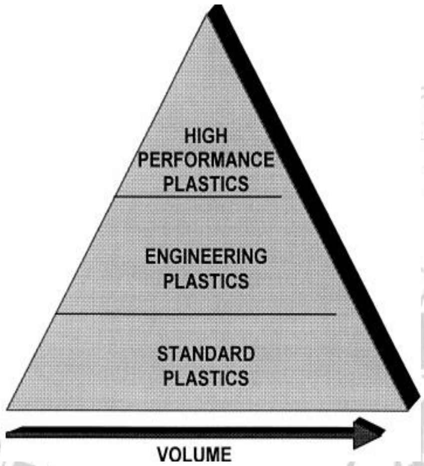

Fig. 2. Standard classification of plastics

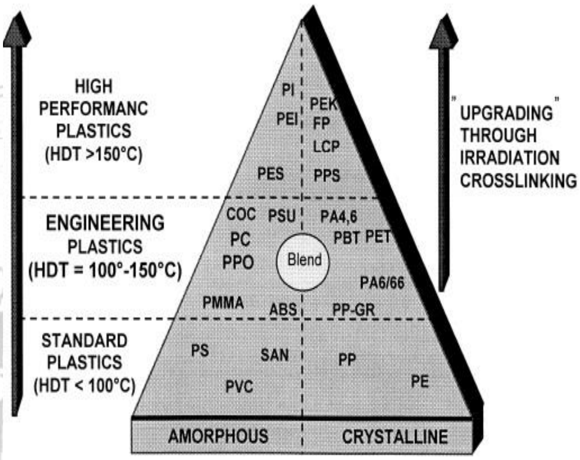

Fig. 3. Up-gradable plastics using radiation

One classification of plastics can be made from the point of view of heat resistance temperature and tensile strength. In fig. 2, plastics are divided by 3 categories: standard plastics, engineering plastics and high performance plastics. Engineering plastic exhibits a heat resistance temperature >100 C^0 and tensile strength >50 MPa. Super engineering plastic is defined as a plastic that exhibits a heat resistance temperature >150 C^0. In fig. 3 there are shown individual types of plastics and their international abbreviations. Crystalline and partially crystalline plastics are suitable for cross-linking. Some of these plastics, for example polyethylene (PE), can be more or less readily radiation cross- linked without any need for special cross-linking additives. Others, on the other hand, polyamide (PA), require the addition of additives prior to processing in order that cross-linking reactions can be triggered during the radiation process [7].

2. Radiation improvable plastics

Depending of the plastic role and placement in the car, there are different technical requirements that it has to comply with. Most polymers required radiation dose frequency between 15 and 200 kGy.

2.1. Polypropylene (PP) foam not only absorbs shocks and impacts very well but also thermally insulates cables and electronic components. Thanks to special additives, it can withstand fires and temperatures of up to 140°C, as confirmed by UL 94 tests [8]. It is used for bumpers, fuel systems, dashboards, panels, electrical components, battery boxes etc. Commercial polypropylenes (iPP) of different molecular weights were irradiated with a Co-60 source at dose of 12.5 kGy in the presence of acetylene in order to promote the crosslinking. The mechanical and rheological tests showed a significant increase in melt strength and drawability. The characterization of the molecular modifications induced by gamma irradiation of isotactic polypropylenes under acetylene atmosphere proved the existence of branching, crosslinking and chain scission in a qualitative way. Therefore, PP irradiation under acetylene was proved to be an effective approach to achieve high melt strength polypropylene (HMSPP) [9]. Also, expanded polypropylene EPP is already used today both as a raw material for the production of protective packaging for batteries and insulation components in battery packs especialy for electric cars [10]. Polypropylene is one of the lightest plastics available with a density of 0.905 g/cm². It is extremely chemically resistant and almost completely impervious to water. Black PP has the best UV resistance and is increasingly used in the construction industry [11].

2.2 PBT (polybutylenes terephthalate) and PA (polyamide) are used in fuel systems, under-bonnet components, electrical components, exterior trim etc. The use of radiation crosslinking of such engineering plastics is under commercial production. Usually, radiation crosslinking accelerators such PFM and TAIC are used to enhance the radiation crosslinking at room temperature. Radiation cross-linked PA 6 PA 66 are mainly used for two of their advantages: a higher service temperature (long-term stability, improved heat distortion temperature and improved chemical resistance to zinc dichloride [12]. PA 6, PA 66, and PBT are used for surface-mounted devices (SMDs) and 3-dimensional molded interconnected devices (3D-MIDs) [13].

2.3 Polymeric Fiber-Reinforced Composites materials consist of a plastic matrix and reinforcing fibers. The functions of the matrix are to act as a binder for the fibers, to transfer forces from one fiber to the other and to protect them from environmental effects and effects of handling [14].

Most of commercially available polymeric composites are reinforced by glass fibers, carbon fibers, aramid fibers (e.g., Kevlar) and, to a lesser degree, boron fibers. These composites offer a wide range of advantages because the structures are the high strength/low weight ratio but also stiff, strong and durable. Carbon fiber – reinforced composites offer new design possibilities for structural components in cars. For example, irradiation of composite materials can increase the adherants of materials, crosslinking of one or more materials and curing of diffrent car parts like fenders. Electron beam curing of composites is compatible with most of the modern composite fabrication technologies, such as prepregs, filament winding, resin transfer molding etc.

3. Conclusions

This paper summaries the application of modified plastics using radiation processing in the automotive industry. The current and emerging new challenges for car production pushes the development of new materials, plastics, that replace the existing ones based on metals. Replacing most of the steel parts, including the chassis and frame, with composites could reduce the weight by 80%, which would double the fuel efficiency. In addition, composite structures would not need corrosion protection coatings, being inherently corrosion resistant. Fiber reinforced composite can be cured while still in the mold in less time than is needed for thermal curing [15]

Even though some plastics have a low resistance for radiation processing, the usage of radiation crosslinking accelerators turn these plastics into highly reliable materials like the case of some popular plastics PBT, PA, PP etc.

Some of its application follow to improve properties for wires and cables, heat-shrinkable materials, pipes and tubes, self-limiting heating cables, resettable fuses, and other formed parts. Plastic foams and hydrogels have been manufactured by radiation crosslinking and rubber materials have also been crosslinked (vulcanized) by radiation. Radiation curing of coatings and inks can be solvent free or use significantly reduced volatile organic compounds (VOCs) [13].

The radiation processing technology allows for economic and environmental benefits. This translates into low pollution and low energy consumption along with its potential in polymer recycling making it a green technology with exceptional attractiveness.

REFERENCES

[1] http://adapt.mx/plastics-in-the-automotive-industry-which-materials-will-be-the-winners-and-losers/

[2] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-transport_en.pdf

[3] https://knaufautomotive.com/plastics-in-automotive-construction

[4] ErizalAbbas, E., Abbas, B., Sukaryo, S. G., and Barleany, D. R. (2015), *Synthesis and Characterization Superabsorbent Hydrogels of Partially Neutralized Acrylic Acid Prepared Using Gamma Irradiation; Swelling and Thermal Behavior*. Indones. J. Chem. 15, 281–287. doi:10.22146/ijc.21197

[5] Bhattacharya, A., and Misra, B. N. (2004), *Grafting: a Versatile Means to Modify polymersTechniques, Factors and Applications*, Prog. Polym. Sci. 29, 767–814. doi:10.1016/j.progpolymsci.2004.05.002

[6] Hans de Brouwer, *Comparison of the effects of x-ray and gamma irradiation on engineering thermoplastics*, Radiation Physics and Chemistry 193 (2022) 109999, https://doi.org/10.1016/j.radphyschem.2022.109999

[7] Joachim Gehring, *With radiation crosslinking of engineering plastics into the next millennium*, Radiation Physics and Chemistry 57 (2000) 361±365, https://doi.org/10.1016/S0969-806X(99)00405-3

[8] https://knaufautomotive.com/plastics-in-automotive-construction/

[9] Adriana Yoshiga, Harumi Otaguro, Duclerc Fernandes Parra, Luís Filipe C. P. Lima, Ademar B. Lugao, *Controlled degradation and crosslinking of polypropylene induced by gamma radiation and acetylene*, Polymer Bulletin volume 63, pages397–409 (2009), DOI 10.1007/s00289-009-0102-7

[10] https://knaufautomotive.com/epp-components-in-the-manufacture-of-batteries-for-electric-cars-applications-and-benefits/

[11] G. Gamow, Akshat Patila, Arun Patela, Rajesh Purohitb, *An overview of Polymeric Materials for Automotive Applications*, 5th International Conference of Materials Processing and Characterization (ICMPC 2016), https://doi.org/10.1016/j.matpr.2017.02.278

[12] Sophie Rouif, *Radiation cross-linked plastics: a versatile material solution for packaging, automotive*, Electrotechnic and Electronics, Radiation Physics and Chemistry 71 (2004) 525–528, doi:10.1016/j.radphyschem.2004.03.050

[13] Keizo Makuuchi, Song Cheng, *Radiation Processing of Polymer Materials and its Industrial Applications*, p 127, Published by John Wiley & Sons, Inc., Hoboken, New Jersey, 2012

[14] D. Jiri George Drobny, *Radiation Technology for Polymers*, Second Edition, CRC PressTaylor & Francis Group, 2010, International Standard Book Number-13: 978-1-4200-9405-3 (Ebook-PDF)

[15] https://www-pub.iaea.org/MTCD/publications/PDF/P1433_CD/datasets/papers/ap_ia-04.pdf