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Development of a polymeric fuel tank with high barrier properties

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Development of a polymeric fuel tank with high barrier properties

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Abstract. The choice and justification of the polymeric material is made for the fuel tank. It is established a possibility of linear polyethylene application with technology of fluorination as material for production of the fuel tanks with high barrier properties, that is with low permeability in relation to hydrocarbons. The main technological operations for the production of plastic fuel tanks carried out by rotational molding are described.

1. Introduction

The plastic has become the main material used by manufacturers of fuel tanks. In Europe, 90% of all fuel tanks are made of plastic. In the US, more than 75% of automotive fuel tanks are made of laminated plastic with a barrier layer.

The plastic fuel tanks are made from the polyethylene of average and high firmness - strong and light material which allows producers of cars to reduce significantly the lump of the vehicle and to achieve more economic consumption of fuel.

The use of plastic for the production of fuel tanks also makes it possible to make the car safer in the event of an accident. Unlike metal fuel tanks, many plastic tanks can bend and flatten, and not burst and crack with a gasoline spill. It allows preventing outflow of gasoline which can cause a fire and explosion.

The use of plastic for the production of fuel tanks allows vehicle designers to optimize the space used for placing of the fuel tank, thanks the possibility to give to tank the most specific form. The plastic can be formed around objects of any shape. In addition, the plastic fuel tanks are resistant to corrosion, whereas in the case of manufacturing tanks from steel for ensuring the same level of corrosion resistance it is necessary to use a noncorrosive steel that leads to increase in expenses.

2. Body text

The plastic as a material has several advantages over metals, such as low weight and ease of processing. Thus, it becomes the preferred material for the components of the fuel system of the car. Production of multi-layer plastic fuel tanks has gained considerable momentum over the past ten years [1-7].

The main disadvantage of polyethylene as a tank material is high permeability in relation to hydrocarbons, due to the low degree of polarization of polymer macromolecules and weak bonds between the chains of macromolecules. In the absence of through defects in the tank wall, its tightness is entirely determined by the permeability P of the material in relation to gases diffusing through the wall, which, as it is known, represents of the solubility C of a gas by the diffusion coefficient D :

$$P = C \times D.$$



The permeability of the polymer depends on the nature of the diffusing gas (chemical composition of the fuel), its solubility in the polymer and the surrounding conditions. The diffusion is accelerated by increasing the difference in concentrations of the diffusing substance on both sides of the tank walls and by decreasing their thickness. The solubility of gas more in amorphous zones of polymer also decreases with increase in degree of crystallinity. The presence of alcohols – methanol and ethanol, introduced to increase the octane number, in the composition of the fuel mixture leads to a significant increase in the diffusion of fuel from the tank cavity to the outside. The presence of alcohols – methanol and ethanol, introduced to increase the octane number, in the composition of the fuel mixture leads to a significant increase in the diffusion of fuel from the tank cavity to the outside. The increasing requirements for environmental protection impose increasingly stringent requirements for the emission of hydrocarbons from the vehicle as a whole, and from the fuel system, the main element of which is the fuel tank.

As the monolayer tank from polyethylene cannot provide necessary balance of mechanical durability, low gas permeability in relation to hydrocarbons and processability at low cost, to reduce the diffusion of hydrocarbon it was developed a number of methods for improving the barrier properties of fuel tanks walls (shareware - barrier technologies). These methods are a fluoridation and a sulfonation.

The fluoridation consists in treating the inner surface of the tank with a gas mixture containing nitrogen (99%) and fluorine (1%), as a resulting in the fluorine atoms replace the hydrogen atoms in the surface layer of the polymer. Depending on the reaction conditions, $=CHF$, $=CF_2$ or $-CF_3$ groups are formed, and the molecular structure of the surface layer of HDPE becomes more densely packed compared to the initial polymer, therefore, the solubility of hydrocarbons in the surface layer decreases, it is lead to a corresponding decrease in permeability. The main parameters of the process are the partial vapor pressure of fluorine, the contact time of the working gas with the walls of the tank and the temperature. The amount of fluoride in HDPE should be such as to provide a reliable barrier without degrading the mechanical characteristics of the tank. An important factor is also the structure of the surface: if it has a so-called wrinkled appearance, the probability of cracking is reduced. The fluorinated polymer is not “absolutely” impenetrable, and hydrocarbon vapors diffuse through it in small amounts – 1-2%.

The sulphonation means by itself that sulfur trioxide SO_3 is introduced into the cavity of the tank, after its manufacture, and as a result of the reactions taking place, a barrier layer of sulfo groups is formed in the surface layer of polyethylene. The neutralization of the reaction by products is carried out with ammonium hydroxide, the excess of which is removed after washing with water. Here, the mechanism for reducing permeability is the same as in the case of fluoridation. The lack of sulfonation is the dispersion of permeability values when processing different tanks.

Modern production of plastic fuel tanks is carried out by rotational molding – a production process which is used for processing the polyethylene in plastic products [8-10]. This process makes it possible to design plastic fuel tanks of complex shape, which will be formed around the free space of the vehicle. The rotational molding allows the use of a variety of workpiece shape, which consists of several parts, so that the product is easily extracted from the tooling.

Rotational molding consists of four main operations (Figure 1):

1. The filling the blank form with powder resin at $50^\circ C$;
2. The closing the form, heating up to $300^\circ C$, holding. In the process of heating the form with the workpiece rotates around its own axis and also around the central axis of the equipment, using centrifugal force. During the heating process, the plastic melts and abuts against the walls of the mold;
3. A cooling the mold by using fans. Air is blown through the walls of the mold, and the workpiece is cooled to a temperature of $70^\circ C$.
4. The hardening of polyethylene and removal of the product from the mold.

The rotational molding is a universal method of processing polymeric materials, which allows producing high-quality competitive products for various applications.

For rotational molding, special grades of polyethylene are used: PE 6432 R (32604) [11], PE 6433 R (32604) [11], PE 6438 R [11], Borealis Borecene Compact RM7406, ROTOPOL UR 644.

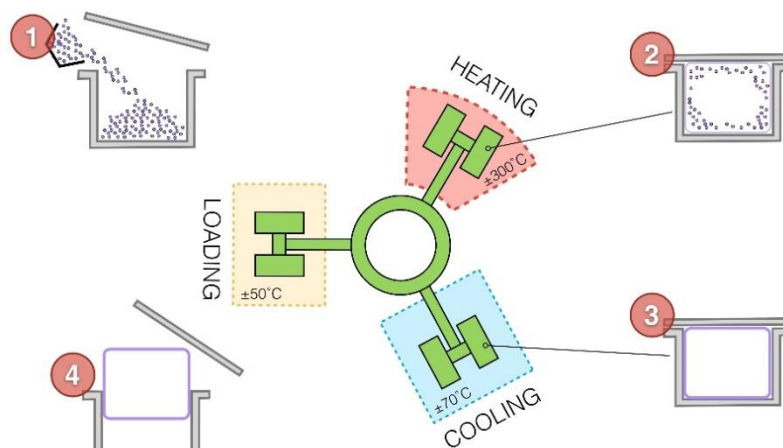


Figure 1. Rotational operation

Analysis of the quality characteristics of polyethylene raw materials for the manufacture of fuel tanks, suitable for rotational molding, revealed the absence of competitive domestic material in price and quality. To improve the properties of the raw materials, it is necessary to use various additives, that is, to carry out an additional process of compounding, and then grinding for the required fraction of rotational molding.

3. Conclusions

Based on the analysis of open sources, it has been established that plastic fuel tanks are made of medium and high density polyethylene. It is established that the main disadvantage of polyethylene as a material for a tank is high permeability with respect to hydrocarbons, due to the low degree the polarization of polymer macromolecules and weak bonds between the chains of macromolecules. This disadvantage is eliminated by methods of improving the barrier properties of the walls of the fuel tanks.

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