

CONSIDERATIONS ON BUILDING PLASTIC FUEL TANKS AND THEIR ATTEMPT TO FIRE TEST

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ABSTRACT: Increasingly, more fuel tanks fitted on the motor vehicles are made of plastic. The multilayer construction of the fuel tanks provides them with the capability to meet the requirements of international regulations in this field. One of the important requirements imposed to a fuel tank is their resistance to fire. This paper presents the experimental fire testing of a multilayer fuel tank.
KEY WORDS: fuel tank, fire resistance, multilayer structure.

1. INTRODUCTION

Since the '70s, carmanufacturers have made and continue to make great efforts towards improvement of the fuel economy of vehicles. The main study direction was the use of different materials, as a replacement for metal parts. At that time, the average weight of vehicles was increasing and therefore the market urged them to continue to find materials to reduce the weight of the cars, thereby helping to reduce the fuel consumption. Due to this requirement of the market, over the last 20 years the average weight of the cars fell by almost 180 kg, while the amount of plastic used in car increased steadily.
Today, the plastics represents 50% of the volume of material used in automobiles, while contributing, on average, with not more than 10% of the total weight of the vehicle. More than any other aspect of the changes implemented with each new car model, reducing the total mass of the car is the one that provides the greatest efficiency. Less weight means better dynamic performance, low emissions and better fuel economy. They can also be improved the comfort, the braking performance and the driveability of the vehicle by better distribution of weight and lowering the centre of gravity.

The fuel tanks made of plastic have become a key component of the automotive passive safety system, offering major advantages compared to classical solutions. In addition to being designed into almost any desired shape, so improving the use of availablespace, in comparison with those made of metal they offer a superior performance to impact and to exposure to heat and a lighter weight and a good resistance to corrosion.The current design also incorporates the fuel supply system, which includes the fuel pump and the fuel filter. Most of those parts are made of POM (Polyoxymethylene), a material which combines high resistance to fuels and chemicals, with good durability under high temperatures, as well as being a good electrical insulator. In addition, plastic fuel tanks also incorporates a valve which helps to maintain the pressure in the container below the permitted maximum and, in some cases, even the carbon canister, which form a complex system for safe storage and delivery fuel (Figure 1).

Figure 1. The systems for storage and fuel delivery, made of plastic.

The current legislation on validation and testing of plastic fuel tanks provides that the main functions they must fulfil are:

- safe storage of fuel during the entire period of operation of the vehicle in extreme conditions of pressure, temperature and vibration. It also includes requirements related to crash tests and fire resistance;

- fuelling the engine;
- indication of the correct fuel level in the tank;
- ensure safe filling of the fuel tank;
- reduce evaporative emissions of hydrocarbons.

The requirements for validation and testing of tanks [1] are directly related to these requirements and to their maintaining for the duration of normal operation of the vehicle.

2. THE REQUIREMENTS FOR THE APPROVAL OF THE FUEL TANKS WITH REGARD TO THE PREVENTION OF THE FIRE RISKS

Regulation ECE R34 includes the following requirements apply to all fuel tanks, regardless of the material they are made of:

a. fuel tank needs to be resistant to corrosion;

b. after fitting all the accessories which are normally attached to them, the fuel tanks must meet the requirements of tightness test at an internal pressure approximately equal to twice of the maximum operating pressure, but under no circumstances less than 30 kPa. It is considered that the fuel tanks made of plastic meet this requirement if they have passed the test described in ECE R34,Annex 5, paragraph 2;

c. any pressure above the operating pressure must be automatically compensated by the system components (such as, for example, safety valves);

d. fuel tank ventilation system should be designed in such a way as to avoid any risk of fire. In particular, any amount of fuel that may escape through the leak areas when the tank is filled, it must not touch the pipe or the muffler;

e. fuel tank must not form a surface of the compartment occupied by the passengers (floor, wall);

f. there must be provided an interior divider structure to separate the passenger compartment and the fuel tank;

g. each fuel tank must be securely fitted on and placed so that any leakage of fuel from the tank or its components may not be able to enter freely in the car, during normal operation conditions;

h. fuel does not have to escape through the cap or through the device for clearing the excess pressure during operation of the vehicle. If the vehicle is reversed, small leakage of fuel can be tolerated if it does not exceed 30 g / min. This requirement shall be verified during the rollover test described in Section 6.2 of the Regulation;

i. the seal between the cap and the filler neck must be maintained for all operating conditions of the vehicle;

j. the fuel tank must be installed in such a way that it is protected during the frontal, side or back collision. Sharp edges and penetrating components must be avoided in the surrounding area of the fuel tank;

k. the tank and the filler neck must be designed and installed in the vehicle in such a way as to avoid any accumulation of static electricity on the entire surface. If necessary, it must be downloaded to the metal structure of the chassis or to another major metal structure, electrically conductive;

l. the fuel tank must be made of fire-resistant metallic materials. If the fuel tank is made of plastic, it must meet the requirements of Annex 5 of the Regulation.

3. THE FIRE RESISTANCE TEST

The requirement of this test is as follows: the fuel tank assembled with all its components and fixed in the same manner as in the vehicle (Figures 2 and 3) is to be exposed to fire for a period of two minutes. At the end of the test it does not be accepted any fuel leak from the fuel tank.

Three tests must be carried out as follows:

A. If the fuel tank is designed to equip a vehicle with gasoline engine, for the three test the fuel tank will be filled to 50% capacity with premium gasoline;

B. If the fuel tank is designed to equip a vehicle with diesel engine, for the three test the fuel tank will be filled to 50% capacity with diesel.

Since the test is destructive, each of the three tests will use another fuel tank assembly.

The Regulation ECE R34, Annex 5, specify the requirements for the tray in which will be put the gasoline that will generate flame during the test. The same regulation specifies the distance between the surface of the liquid (gasoline) in the tray and the bottom of the tank. The amount of gas in the tray must be sufficient to ensure the maintenance of the flame throughout the test.

Figure 2. The test bench.

Figure 3. The fuel tank installed for test

In addition, the fuel tank is equipped with sensors which measure the temperatures at various points in the vicinity of the tank. Also, during the test the pressure inside the plastic fuel tank is monitored.

4. THE EXPERIMENTAL TEST

The test consists of four distinct phases as follows: 1 - generating the flame and bring it to the temperature of the test;

2 - direct exposure of the fuel tank to flame;

3 - indirect exposure of the fuel tank to flame;

4 - end of the test.

Phase 1. Generating the flame and bring it to the temperature of the test (Figures 4 and 5) The duration of this phase is not specified in the regulation. As can be seen, the tray with the ignited fuel must produce a flame strong enough to expose the fuel tank to the test temperature.

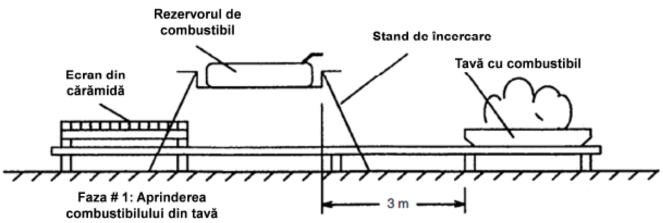

Figure 4. The scheme of the phase 1 of testing the fuel tank.

Figure 5. Running the phase 1 of testing the fuel tank.

Phase 2. Direct exposure of the fuel tank to the flame (Figures 6 and 7).

After the fire is lit, the fuel tray is moved under the fuel tank which is mounted on the vehicle. The fuel tank is then exposed to direct flame during one minute.

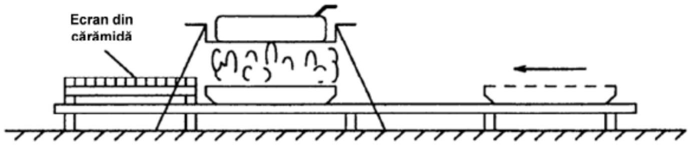

Figure 6. The scheme of the phase 2 of testing the fuel tank.

Figure 7. Running the phase 2 of testing the fuel tank.

Phase 3. Indirect exposure of the fuel tank to flame (Figures 8 and 9).

After passing the first 60 seconds, a special barrier is introduced between the flame and the fuel tank. This barrier is made of bricks whose structure and size are defined in Appendix 5 of the Regulation ECE R34. Over the next 60 seconds, the fuel tank is exposed to heat radiated mainly from this barrier made of bricks.

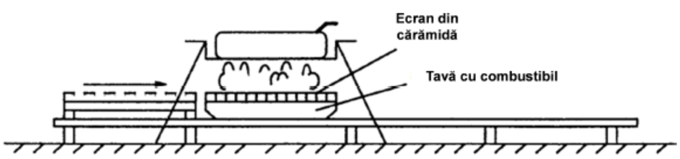

Figure 8. The scheme of the phase 3 of testing the fuel tank.

Figure 9. Running the phase 3 of testing the fuel tank.

Phase 4. End of the test (Figure 10)

At the end of the third phase, the barrier made of bricks is removed as soon as possible from under the fuel tank and the flame is extinguished. As previously mentioned, to pass this test, three fuel tanks with the same design should be tested. No fuel leakage is permitted during these three tests.

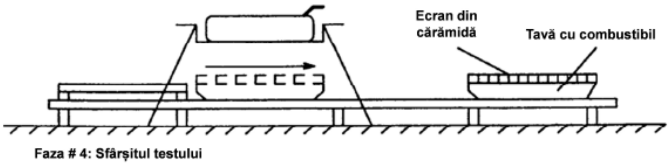

Figure 10. The scheme of the phase 4 of testing the fuel tank.

5. RESULTS. CONCLUSIONS

Figure 11 shows a fuel tank that does not meet the requirements for approval in the fire resistance test. For comparison, Figure 12 shows another type of fuel tank which successfully met this test.

Figure 11. The fuel tank that did not met the requirements regarding the fire resistance test.

Figure 12. The fuel tank that did met the requirements regarding fire resistance test.

In order to achieve the performance of resistance in such extreme test conditions which simulate the extreme conditions likely to be encountered in practice when the car is burning, the fuel tank is made of plastic with a multi-layer structure, replacing the single-layer construction made before.

The multilayer structure was first used in mass production of fuel tanks in 1994, following the introduction of the LEV I regulations in United States that impose limitations to the evaporative emission level of the fuel tank made of plastic. Consisting of 5 or 6 different layers, the structure is commonly used in the proportion of 100% on the market for plastic containers produced in North America and Japan. The most commonly used structure, the 6-layer [3], is shown in Figure 13 and has the following structure (from outside the fuel tank to inside):

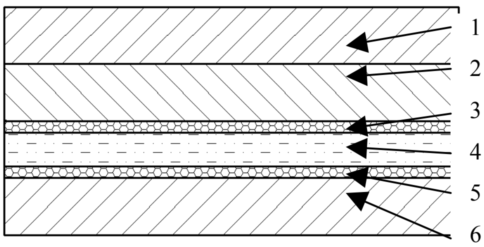

Figure 13. The fuel tank multilayer structure: 1 - HDPE, 2- regrind, 3 - glue, 4 - EVOH, 5 - glue, 6 - HDPE.

Where:

- HDPE - high density polyethylene;
- Regrind - recycled material;
- Glue - adhesive;
- EVOH (Ethylene vinyl alcohol co-polymer) - material acting as a vapour barrier;
- Glue - adhesive;

During the extrusion of the material of the fuel tankit is used for each layer a single-shaft gear, known as the "extruder". In order to compensate the different flow rates of each material, it is used a continuous extrusion process,briefly called "co-ex". The role of the vapour barrier is achieved by the material named "Ethylene vinyl alcohol co-polymer" which is known by the acronym of EVOH. Taking in the consideration the incompatibility between this material and the polyethylene, it is necessary to integrate two layers of glue which provides adhesion of these materials and, at the same time, the integrity of the structure as a whole.

The future trends in fuel tank construction are turning to generalize this construction to the structure shown in Figure 13, since it meets all the requirements for approval in the EU countries, in America, Asia and Japan.

6. REFERENCES

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