Complex Development for Tank Systems

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In the past, fuel systems were relatively simple structures which stored gasoline or diesel. However, in recent years they have become highly complex. Increasingly stringent emission legislation and the introduction of new fuels and additives as well as powertrain hybridisation have all had a major impact on the development of a modern tank. Bertrandt develops and verifies new concepts for refuelling and ventilation, including the examination of noise behaviour and more complex development processes.

TRADITIONAL FUEL TANKS

Modern tank systems have to meet a far wider range of requirements than was the case ten years ago. It is not only the higher standards imposed by customers in relation to quality and safety of the fuelling process, but also the legislative provisions and regulations put into effect by countries' authorities that have transformed tank systems into highly complex components with equally complex development processes.

The most recent trend is the use of plastic fuel tanks in conventional vehicles. Here, the term "conventional" in the context of tank systems is used to distinguish between traditional tank systems and those in Plug-in Hybrid Electric Vehicles (PHEVs). The multi-layer plastic bladder tank offers advantages in terms of the variety of shapes that are possible and an improvement in the permeation behaviour, so the ability of a material to be diffused by a substance (a permeate; such as a gas). In addition to the increasingly strict standards for exhaust emissions of a passenger car, stringent requirements are also being imposed on the emissions from evaporation processes [1, 2].

The integral ventilation system in the tank, which is connected with the Activated Carbon Filter (ACF), is responsible for the gas exchange when the car is being refuelled or driven. Depending on the national regulations in question, the gas that is displaced during refuelling is either actively extracted from the filler pipe by the fuel pump nozzle of the

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gasoline station or passed through the ACF to remove the fuel vapour.

In addition, the gasoline vapour generated by the sloshing movements of the fuel in the tank or an increase in temperature can also be discharged into the ACF in order to ensure that the pressure in the tank remains within its operational limits. Another advantage of plastic tanks is its high level of elastic deformability in the event of a crash. All of these functions are required to meet very high standards by the vehicle manufacturers and the relevant legislation authorities.

PRESSURISED TANK SYSTEMS FOR HYBRID VEHICLES

Another challenge for tank developers is the increase in the hybridisation of vehicle drives. Traditional tank systems with open ventilation processes cannot be used in a PHEV (in pure electric driving and charging operation mode). The fuel vapour adsorbed by the ACF cannot be passed to the combustion engine for burning if the vehicle is in pure electric mode. In addition, the ACF cannot be regenerated. As a result, the working capacity of the filter will be exceeded and harmful hydrocarbon molecules will be emitted. In order to prevent this from happening, the ventilation system of the fuel tank is kept separate from the outside world by a fuel tank isolation valve.

The vapour that is still produced in the tank leads to an increase in pressure, but, as the pressure rises, the rate at which the vapour is emitted reduces. For this reason, pressurised tanks are used in PHEVs. These tanks are made of steel or specially reinforced plastic to enable them to withstand the increased pressure and meet the stricter emission requirements.

ACOUSTIC CHALLENGES

For owners of traditional vehicles, the important considerations are a lack of noise from the tank and the ability to refuel the vehicle safely and reliably. Lack of noise caused by the automatic stop-start system of the combustion engine as well as by electrification of vehicles increases the amount of development work required to introduce active and passive measures in and around the tank system. One widely used technical NVH solution consists of swash plates inside the tank which prevent the fuel from sloshing. In addition, rubber mounts are fitted to isolate the tank at the points where it is fastened to the vehicle body in order to minimise structure-borne noise. The ability to refuel the vehicle safely also requires a carefully designed filler pipe.

ENVIRONMENTALLY FRIENDLY TANK SYSTEMS

In the light of the growing restrictions on tank systems, ACFs are playing an increasingly important role with regard to triad “environmental protection – emissions – end customer” for fuel systems. The highly flammable vapour emitted by gasoline not only smells extremely unpleasant but also contains hydrocarbons that need to be captured because they are harmful to human health and the environment.

The main factors that influence the evaporation rate include the vapour pressure and the existing temperature of the fuel but also the dynamic stimulation of the fuel caused by the movement of the vehicle. Usual, traditional tank systems cannot counteract the formation of vapour by means of an isochoric increase in pressure. As a result, the gas volume flow is taken outside the tank externally for an aftertreatment.

MASTERING EMISSIONS

One solution that has been in use for several years involves capturing the hydrocarbon emissions that have a harmful impact on the environment using the activated carbon of the ACF. The activated carbon is placed in a container in the flow path of the gas and adsorbs the hydrocarbon molecules by means of an exothermic reaction. The gas can then be discharged into the environment without problems.

But alongside this basic loading process for the ACF, a further loading factor needs to be evaluated, with a distinction being made between different countries’ requirements. In this case, vehicles are generally divided into those for the North American market and those for the markets “Rest of the World” (ROW).

SAFE REFUELLING AND ENVIRONMENTAL REGULATIONS

When a tank intended for ROW markets is being refilled, the refuelling system (at the gasoline station) must extract and capture the gas displaced from the tank, which is generally saturated with fuel vapour [2]. In contrast, vehicles for the North American market require an On-board Refuelling Vapour Recovery (ORVR), which involves the vehicle capturing the gas volume displaced from the fuel tank during the refuelling process. This gas volume not only requires to be filtered by the ACF, it also results in a direct correlation between the possible refuelling speed of the entire tank system and the flow resistance of the ACF. This complex interaction means that the system has to be carefully designed and thoroughly validated before

FIGURE 1 Validating the safety and speed of the refuelling process with a test facility (© Bertrandt)

FIGURE 2 Investigating the thawing speed of an SCR system (© Bertrandt)

it is ready for series production and meets all the legislative requirements, **FIGURE 1**.

As the loading of the ACF is a regenerative process, in gasoline engines the inlet manifold vacuum is used to regenerate the filter in an endothermic reaction. The resorbed hydrocarbon molecules are passed into the engine's combustion process. During the development phase, every effort is made to ensure that the working capacity of the filter (the amount of hydrocarbon molecules adsorbed and the amount of activated carbon used) is designed to be as large as necessary and as small as possible. Different types and compositions of activated carbon are available, but granules are most commonly used in ACF.

TANK SYSTEMS FOR SCR SYSTEMS

Modern diesel vehicles are often fitted with another tank in addition to the fuel supply system. This stores the additive for the SCR system of the exhaust-gas aftertreatment, which is needed in order to meet the statutory legal requirements concerning pollution emissions from diesel engines. Selective Catalytic Reduction (SCR) allows large amounts of nitrogen oxide (NO_x) to be removed from the exhaust gas.

In everyday use, this technology presents some challenges, which include the additional space needed for the tank and for other components, such as the SCR catalyst and the dispensing unit. A critical factor is the behaviour of the additive (urea solution, brand name AdBlue) in cold conditions. It freezes at -11 °C and can cause significant deformation of the SCR tank. Therefore, it must be possible to guarantee the operation of the system when the additive is frozen and when the vehicle is travelling short distances, for example by installing a permanent heating for the system. **FIGURE 2** shows an investigation of the thawing speed of an SCR system. Other considerations include the corrosive properties of the urea solution and the refilling process.

It may be necessary for the end customer to be able to fill the tank, depending on the consumption of the additive and the tank size. In the same way as with the fuel tank, every aspect of the refilling process must be tested to ensure that it is safe for end customers.

TESTING AND EVALUATING

Bertrandt has experienced testing engineers who evaluate the basic functions of tank systems, together with the durability and emission behaviour, at each stage of development in order to verify the development concepts and the results of computational simulations. The teams in the company's workshops build test equipment or integrate the parts for testing into the entire vehicle. Measurement specialists can generate comprehensive data concerning temperatures and pressures during a mountain journey at high temperatures or relating to the loading factor of the ACF container.

In the test facility for fuel systems and environmental simulation, tests are carried out throughout the development process, for example to reduce the amount of work involved in road trials, but also to allow for the greatest possible flexibility.

Because the design of the tank and the filler pipe geometry is becoming increasingly complex as a result of the growing number of vehicle derivatives, the challenge is to create a ventilation system for the tank which will allow it to be refuelled as efficiently as possible and enable end customers to refill their cars without problems. Bertrandt is currently testing systems with around 50 different filler nozzles, depending on the country they are intended for and the fuel type (EU, USA, and China as well as gasoline/diesel). Other factors include the different filling speeds at gasoline stations throughout the world, which range from 15 to 60 l/min. The different positions of the filler nozzle also have to be tested in order to cover every common type of end customer behaviour.

The cases highlighted here, which can occur in reality anywhere in the world, make it clear how much testing is needed simply with regard to the quality and safety of the refilling process to enable a vehicle fuel system to be approved for use by customers. **FIGURE 3** shows a typical refuelling process diagram with the tested features fuel volume, gas recirculation and fuelling speed over time.

The peripheral elements of the fuel supply system also need to be thoroughly tested. Using a special conditioning unit for ACF, the ageing of the filter throughout its life cycle can be simulated by adding and removing fuel vapour or butane. In addition, conclusions can be drawn about the most suitable type of carbon and the current capacity of the filter.

It is also important to ensure that the system does not leak in a worst case sce-

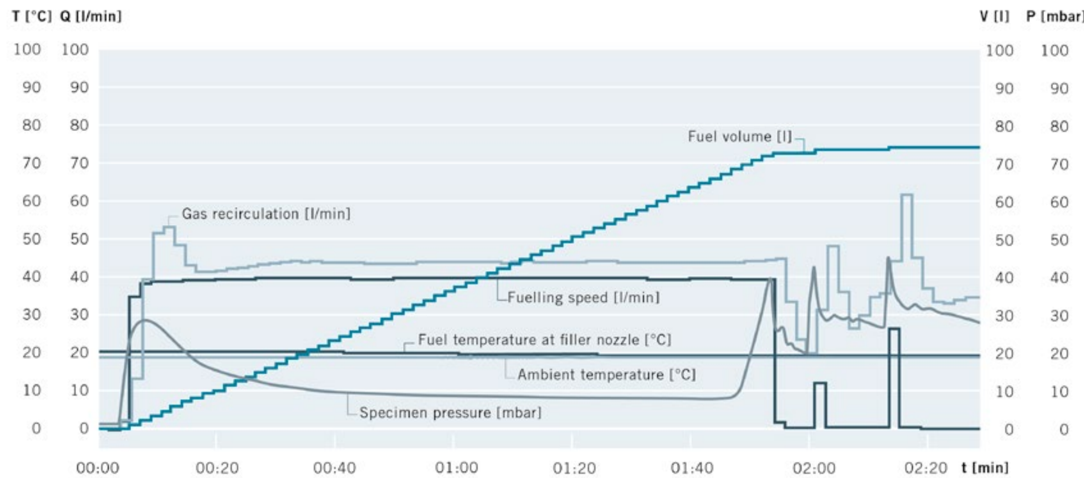

FIGURE 3 Typical fuelling process diagram with the tested features fuel volume, gas recirculation and fuelling speed over time (© Bertrandt)

nario, for example by carrying out crash or roll-over tests. Environmental simulations allow the various influences on the materials used to be assessed, for example by running temperature, salt spray or alternating pressure tests, and the influences on the media in the systems to be evaluated, such as the urea required for SCR. After a series of tests or between the individual phases, the tank system can be placed in a test chamber for Sealed Housing for Evaporative Determination (SHED) regarding its emission behaviour.

COMPLEX PROJECTS – SUPPORT ACROSS A WIDE RANGE OF DISCIPLINES

As a development service provider, Bertrandt provides support across a wide range of disciplines and can take on specific tasks in order to reduce the workload of OEMs and suppliers as well as assuming responsibility for entire complex projects. The service provider's development departments have teams of experienced engineers and specialists in the fields of design and materials engineering who can put the requirements specifications into practice. One relevant factor in this respect is the increasingly small amount of space available for tanks in vehicles, which can result in tanks with very complex shapes.

As more and more electrical and electronic components are incorporated into tank systems, such as new level sensors, different pump technologies, OBD diagnostics modules and own tank electronic control units, additional knowledge of electrical and electronic engineering is needed, **FIGURE 4**, to ensure that these components are integrated reliably into the overall system. Bertrandt also has function developers and application specialists for the relevant operating and diagnostic functions, together with test engineers responsible for testing the systems.

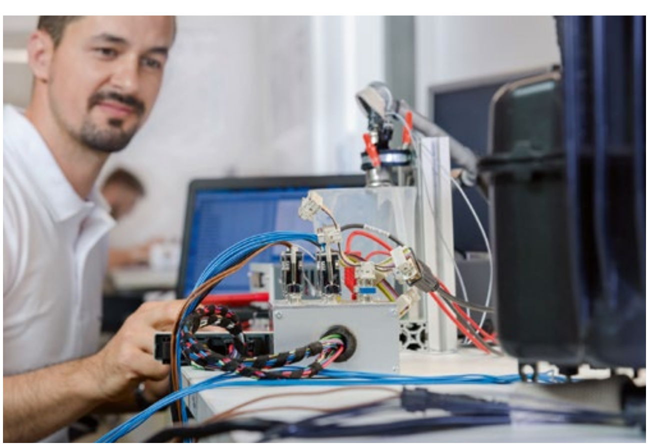

FIGURE 4 Additional E/E knowledge – testing of electrical components in the tank system (© Bertrandt)

CONCLUSION AND FUTURE PROSPECTS

In summary, it is clear that tank systems and all their peripherals are not only responsible for supplying fuels or additives anymore, but also involve the complex interaction of a broad range of components with a variety of functions and requirements relating to the triad "environmental protection – emissions – end customer". The result is a large amount of development work for vehicle manufacturers and system suppliers.

During the increase in the numbers of hybrid and electric vehicles, fuel is still a highly relevant topic for development departments. The complexity of fuel systems will continue to occupy the market players for some years to come. In order to overcome the challenges involved, Bertrandt specialises in providing testing services under real-life conditions to complement the work of its development departments and is expanding its testing facilities at its Mönsheim site near Weissach, Germany, to meet these requirements.

REFERENCES

[1] Gruden, D.: Umweltschutz in der Automobilindustrie. Chapter: Umweltauswirkungen des Automobils. Wiesbaden: Vieweg+Teubner, 2008, pp. 329

[2] Hilger, M.: Alternative Antriebe und Ergänzungen zum konventionellen Antrieb. Chapter 6: Alternative Kraftstoffe. Wiesbaden: Springer Vieweg, 2016, online: https://www.springerprofessional.de/alternative-kraftstoffe/10709556, access: 21 March 2017