A NEW MANUFACTURING PROCESS FOR PLASTIC FUEL TANKS NEXT GENERATION FUEL SYSTEM - NGFS®

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Abstract: *Next Generation Fuel System – NGFS, is a new technology that provides the ability to produce a plastic fuel tank meeting the future customer demands. It provides design freedom for new solutions, an increase in useable volume and offers a solution for plastic PZEV and LEV III fuel systems. Compared with the existing technologies on the market, this new manufacturing process (NGFS) offers the possibility of assembling the valves and other components inside the plastic fuel tank shell which trigger a significant reduction of the evaporative emisssions. Now that the first designs have already been launched in mass production, the paper will introduce our company's vision to obtain a finished fuel tank produced in one production step, together with some of our breaktrough designs that will allow us to achieve this vision. The process that allowed the development of this technology included extensive CAE analysis, sampling and a large amount of testing. The use of 6 Sigma tools and our 6 Sigma focus sets the foundation for product capability. The presentation will cover: What is NGFS ?; Process information; Current status of NGFS; NGFS – functional advantages; Current vehicle applications; NGFS - Vision.*

Keywords – Plastic fuel tanks, reduced emissions, integration of functions and components, LEV III, PZEV

1. INTRODUCTION

Conventional Blow Molding is the main technology that has allowed the manufacturers to produce monolayer and multilayer plastic fuel tanks (PFTs).

In a nut shell, it consists in extruding a cylindrical parison and forming it into different shapes, as required by the design (refer to Figure 1).

Over the years, the boundaries of this technology have been continuously expanded to a point where today's PFTs with a complex shape and system architecture, that meet the most stringent requirements including LEV II and PZEV emissions regulations, can be routinely manufactured at mass production levels (refer to Figure 2).

Figure 1

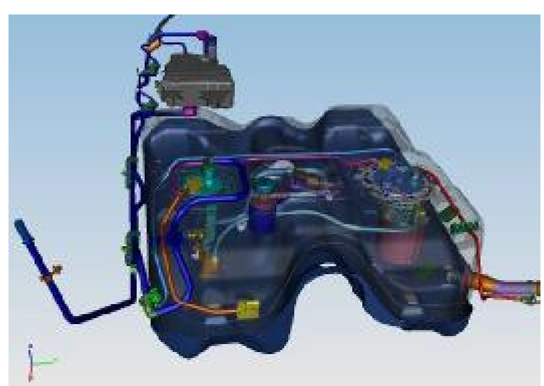


Figure 2

As new regulations are being rolled out and additional requirements such as the use of bio-fuels, meeting LEV III emission levels, hybrid applications and CO2 reduction have to be met, the design engineers started to look for new ways to manufacture the PFTs. Over the last years, as each of the major market players started to develop new manufacturing technologies that will support further advancements in the PFT designs and ensure compliance with the latest regulations, there seems to be a consensus amongst the PFT suppliers that the conventional blow molding technology has reached its maximum potential.

This comes as a confirmation that the concept that: "All engineering systems evolve along an S-shaped curve and pass trough 4 typical stages", also applies to the plastic fuel tank technology. This curve, known as the "evolution" curve of a given system, is shown in Figure 3. It can be seen that in the forth and last stage, it is expected that the systems will reach a plateau where further progress will be difficult to achieve, even with a large investment of resources. The concept further states that in order to facilitate further technological advancements a "revolution", a breakthrough, will need to occur. This usually equates to the development of a new, more advanced, more flexible technology. The S-curve that we have associated with the fuel tank manufacturing technologies is shown in the Figure 4.

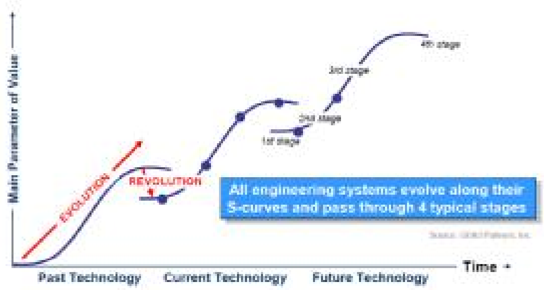


Figure 3

Figure 4

The solution developed by Kautex-Textron in order to address these new challenges, the enabler to meet future market requirements, is the Next Generation Fuel System – NGFS.

2. NGFS - PROCESS INFORMATION

2.1 CO-EXTRUSION DIE

A key contributor to the success of NGFS was the development of the flat 6 layers co-extrusion die, which allowed the transition from the conventional round shaped parison (refer to Figure 5) to the two co-ex sheets, used in the NGFS process (refer to Figure 6).

Figure 5

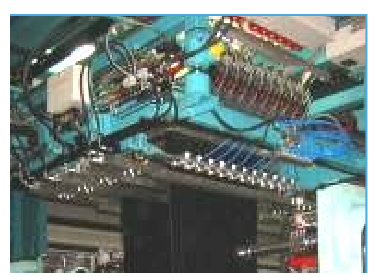


Figure 6

The new head tool design went through an intense development process that included the use of CAE tools. Rheological simulations for production tools were used in order to analyze and optimize the complex transition phenomenon that is taking place in the flat die. In Figure 7 it is shown an example of a pressure drop analysis used for material flow optimization.

One of the most important design limitations faced when using the conventional blow molding, is the ability to place the components inside the PFT. Different solutions have been identified over the years however, only after the introduction of NGFS these restrictions have been successfully addressed.

The main differences between the two processes are identified in Table 1.

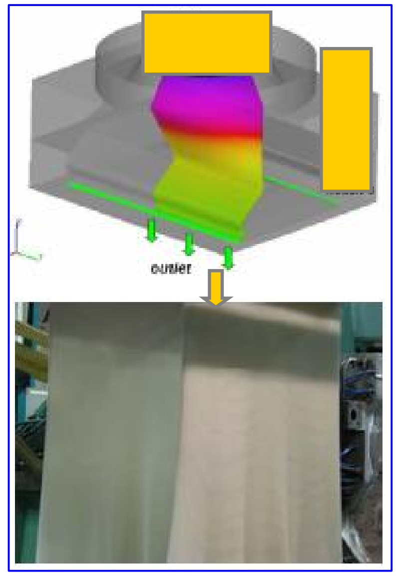


Figure 7

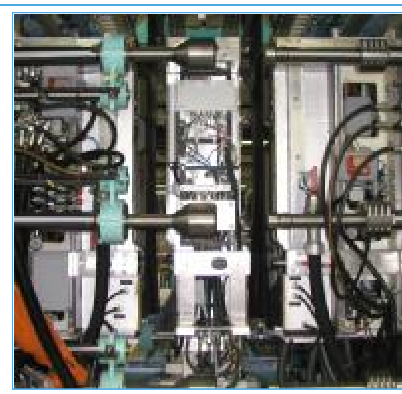
	Conventional Process	NGFS Process
Picture		
Extrusion	Round 6-layer co-ex parison.	Two 6-layer co-ex sheets.
Blow Moulding	Semi finished product is a tank shell, only.	Semi finished product is a tank shell with already integrated main functions (venting, gauging, filling, etc...).
Down Line	All components are welded in subsequent process steps onto outer fuel tank shell.	No or limited subsequent process steps to weld components onto outer tank shell.
Assembly	Fuel Delivery Module, Heat shield and other externally attached components	Fuel Delivery Module, Heat shield and other externally attached components

Table 1

Some of the main process steps that are part of the new NGFS technology are shown in the process diagram below (refer to Figure 8). The diagram consists of top views of the mold as seen from the head tooling side.

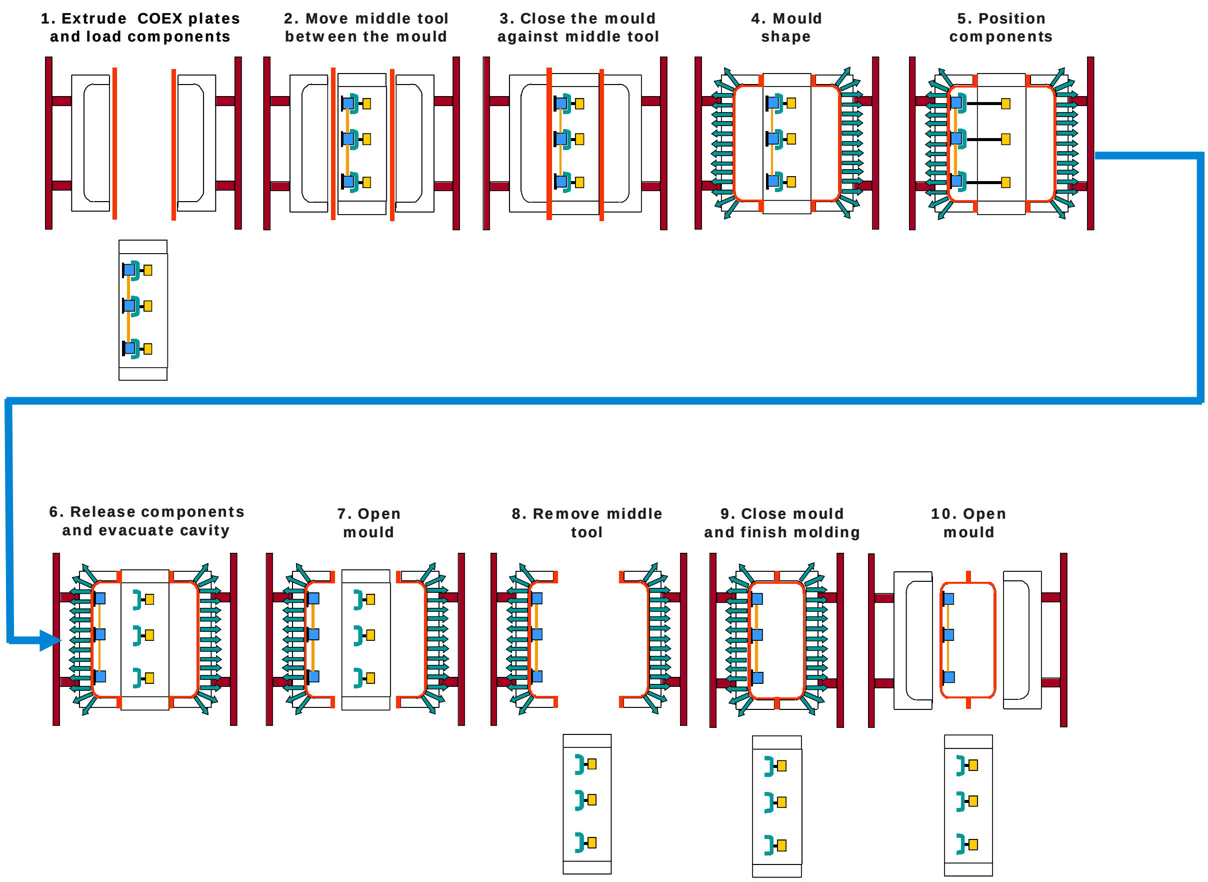


Figure 8

2.2 INTERNAL ATTACHMENT METHOD

In order to deliver the required ability for different components to be placed inside the PFTs, the traditional plastic joining methods such as heat welding, spin welding, ultrasonic welding or vibration welding, could not be easily utilized. New attachment methods between the PFT and key components had to be developed. To achieve this goal, during the past years various designs have been evaluated under extreme testing conditions.

One of the solutions that were adopted is an under-cut shaped connection, formed during the NGFS blow-molding process by pressing the component's supporting bracket, shown in Figure 9, against the inner surface of the extruded plastic sheet. The hot plastic material is forced through the openings specially designed into the bracket and the two are being joined together.

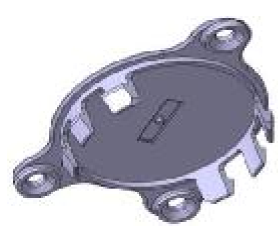


Figure 9

For comparison, in Figure 10 it is shown a connection made on the outside surface of a fuel tank while using the traditional hot plate welding method while Figure 11 shows a similar component being attached on the inside surface of a plastic fuel tank using the NGFS design. Two of the three connecting areas can be seen.

Figure 10

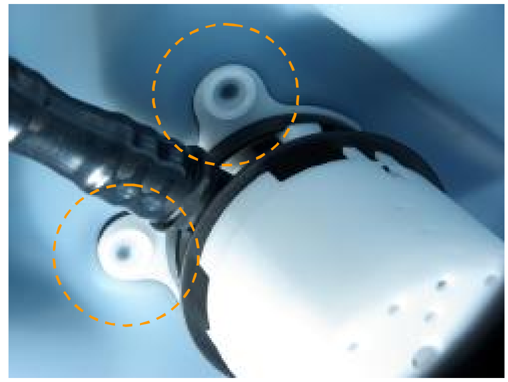


Figure 11

In order to guarantee the correct forming of the connections, the joining process and the related phenomena were analized in detail by performing several iterations of CAE analysis. One of these iterations is presented in Figure 12, where the contact between the bracket and the inner surface of the PFT can be seen. These simulations helped us better understand the material flow in the connection areas.

The final iteration of this new connection design has been already succesfully validated. By allowing the integration of complex functions inside the PFT, it has provided much needed flexibility for the development engineers. The inside of an NGFS assembly is shown in the next section, in Figure 18. The components that can be seen in this view will also be presented in the next section.

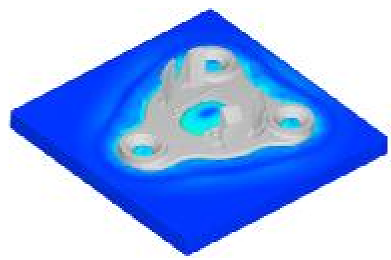


Figure 12

Key to our success was the 4 tiered approach, presented in Figure 13, which started by defining at the beginning the development detailed specifications. This allowed the design team to establish early on clear product related requirements. In addition, the use of 6 Sigma tools and our 6 Sigma focus provided a strong foundation for improving product capability to the expected levels, well before the completion of the pre-production trials. Last but not least, an innovative and reliable test method allows the continuous monitoring of the quality of the connections.

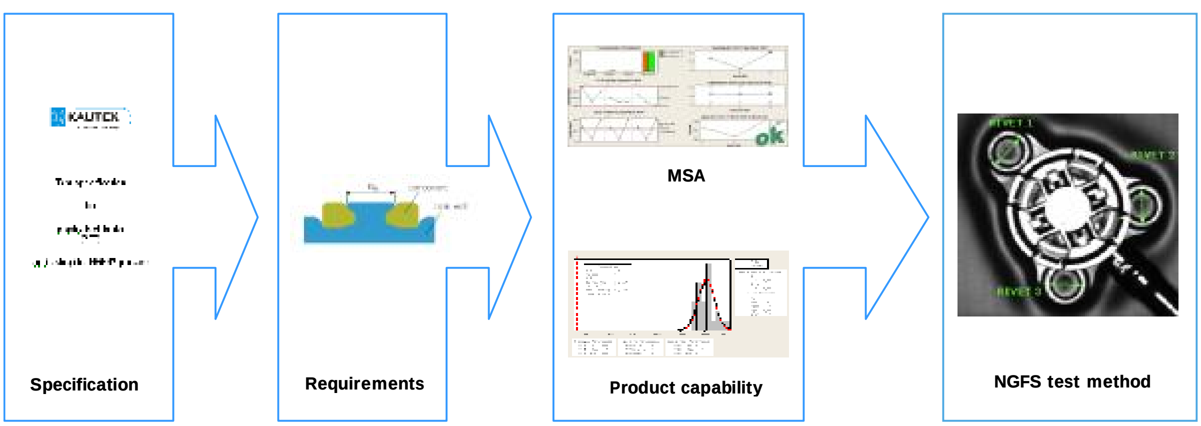


Figure 13

3. CURRENT STATUS

3.1 STANDARDIZED INTERFACES / ATTACHMENTS

The succesfull development of the new NGFS component attachment method, has provided a solid foundation for the design of standardized interfaces and attachments. Depending on the application, these can be categorized as follows:

a. Interfaces for small components (e.g. valves) – refer to Figure 14
b. Interfaces for level sensors & jet pumps – refer to Figure 15
c. Interfaces for large components (e.g. Fuel Delivery Module) – refer to Figure 16

Figure 14

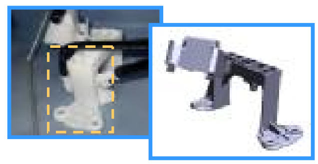


Figure 15

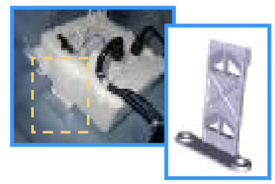


Figure 16

3.2 STRUCTURAL REINFORCEMENT & NOISE REDUCTION

3.2.1 STRUCTURAL REINFORCEMENT

The newly developed attachment method could also be used in future applications for integrating reinforcement components for the tank structure. These are usefull in improving the PFT stifness, a requirement usually linked with the OBD2 and pressure / vacuum performance. New structures designed for the NGFS application are currently under development and are intended to guarantee PFT's compliance with these requirements, while reducing the volume loss penality incurred with most of the designs available when using the Conventional Blow Molding process. One example can be seen in Figure 17.

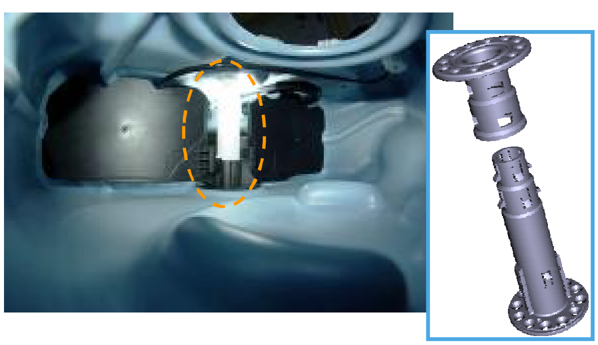


Figure 17

Figure 18

3.2.2. STANDARD INTERFACES FOR BAFFLES

The slosh noise and implicitly the slosh noise reduction, has increasingly became a major factor in the design of a PFT. The introduction of the hybrid applications requires now a supperior performance to be achieved in this area as the sound generated by the movement of the fuel inside the PFT cannot be covered any longer by the noise produced by the engine and can potentially be detected by the end customer, specially when the vehicle runs in the EV(electrical vehicle) mode.

NGFS offers the option of including slosh noise baffles in the PFT design. The NGFS baffles can be attached to the structural reinforcement element presented above and installed inside the PFT during the blowmolding process. An example of this design in presented in Figure 19.

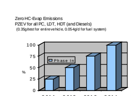
Figure 19

4. NGFS – FUNCTIONAL ADVANTAGES

4.1 MEETS LOW EMISSIONS REQUIREMENTS

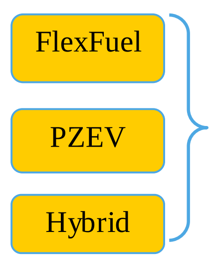
Through the integration of components inside the tank and the elimination of the passive side sender flange attachment, the NGFS process allows for a significant reduction in the number of openings in the tanks shell. Fewer openings will lead to fewer emissions.

PZEV/LEV III



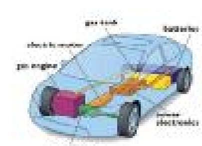
4.2. SUPPORTS OEM STANDARDIZATION STRATEGY

NGFS offers the option of reducing the number of variant required to be developed for different markets or requirements and replace them with a robust modular product design. NGFS allows a one tank shell to be combined with standardized subsystems and components, in order to meet all customer emissions related requirements. This leads to a significant reduction in development cost and time and eliminates the validation content currently associated with the development of different design variants.



4.3 PROVEN SOLUTION FOR HYBRID APPLICATIONS

By allowing the integration of structural reinforcements in combination with the slosh noise reduction features and the already mentioned low emission performance, NGFS became a logical solution for hybrid vehicle PFTs and for these applications it is already used in North America in serial production.



Hybrid

4.4. REDUCTION IN THE OVERALL VEHICLE WEIGHT

By using the better wall thickness control offered by the new flat die design, NGFS can allow for a more uniform tank shell wall thickness distribution to be achieved, with a positive impact on the overall tank shell weight. As an example, for the Ford Escape application, an improvement of 35% was achieved by reducing the weight of the PFT from the 12,05 Kg of the previous steel tank design to a low 7,90 Kg in case of the new NGFS design.

5. CONCLUSIONS

As a result of 4 years of intense development activity, the NGFS technology it is today customer approved and in production for 2 major projects (refer to Figure 20 and Figure 21)

(Picture source: BMW.de)

Figure 20

(Picture source: Ford.com)

Figure 21

In addition, new programs have been awarded and are now in development. Production capacity has been already developed on 2 continents. We can now say that we have successfully met globally our customer's expectations.

New concepts are being currently validated in order to further develop this technology. One key area is related to the pressurized plastic fuel tank systems that are expected to be launched on the market between 2015 and 2016. These revolutionary designs will be used in the hybrid vehicle applications where the vapor management strategy of the vehicle requires the plastic fuel tank to guarantee 15 years durability and to maintain its performance for the same period of time while exposed to a large range of pressure conditions. According to the information available today, this range is expected to be from -100 mbar to + 350 mbar.

The milestones have been defined and today we are well on our way to accomplish the NGFS vision. It is our firm belief that the enabler to meet future requirements for plastic fuel systems is the technology that we've proudly named: Next Generation Fuel System - NGFS.

REFERENCES

[1] Elsasser C., Eulitz D., *Next Generation Fuel Systems NGFS. The way for the future*, Tank.Tech, 2009, Bad Gogging, Germany
[2] Taguchi R., Schmitz M., Elsasser C., *Twin sheet PFT manufacturing process. Next Generation Fuel Systems NGFS*, Doshisha University, 2010, Kyoto, Japan
[3] Gligor A., Elsasser C., Eulitz D., Hannah K., *Next Generation Fuel System – NGFS*, CONAT conference, 2010, Brasov, Romania