Research and constructive solutions on the reduction of slosh noise

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Abstract. The paper presents a product design making of, over a “delicate issue” in automotive industry as slosh noise phenomena. Even though the current market tendency shows great achievements over this occurrence, in this study, the main idea is to design concepts of slosh noise baffles adapted for serial life existing fuel tanks in the automotive industry. Moreover, starting with internal and external research, going further through reversed engineering and applying own baffle technical solutions from conceptual sketches to 3D design, the paper shows the technical solutions identified as an alternative to a new development of fuel tank. Based on personal and academic experience there were identified several problematics and the possible answers based on functional analysis, in order to avoid blocking points. The idea of developing baffles adapted to already existent fuel tanks leaded to equivalent solutions analyzed from functional point of view. Once this stage is finished, a methodology will be used so as to choose the optimum solution so as to get the functional design.

1. Introduction

Automotive industry may be considered a highway for new technology various applications. Each salon amazes in terms of design, horsepower, materials and technical solutions. Together with all these characteristics, there are created new needs for drivers and passengers, also their expectations rise, and the critical spirit, too. Such a specific situation is Start and Stop technology [1]. In this case, the client becomes more sensitive to acoustic performance. The noise level rests the same as in the past (per component), but the client perceives it different. When the engine is turned off at the traffic light, he hears the sound of the waves inside the fuel tank. Translated into noise performance characteristic for the fuel tank, it is called “Slosh noise”. A well-known phenomena generated by fluid movement inside a fuel tank while various scenarios like acceleration, deceleration, breaking etc. are taking place. In fact, during the process of moving the liquid inside the tank storages kinetic energy and the slosh noise is produced when this type of energy is over limit [2]. This kind of inconvenience can be solved by using filter elements in fixation zones, paint protection with acoustic performance, add of insulators, or to redesign a present fuel tank so as to introduce baffles. To decrease the effect of slosh noise, there were patented different solutions of internal baffles or even baffles integrated in the envelope of the fuel tanks. The main inconvenience of the existing solutions is that the fuel tank needs to be redesigned and the production process rebuild, so a completely new concept is developed.
In a world where the strategy is “design to cost” and in the same time “design to quality”, too, the ideal situation is to find a solution to decrease the noise inconvenience generated by the waves inside the fuel tank without modification of its geometry. Therefore, the aim of the study above is to analyze technical solutions of baffles suitable for already existent fuel tanks that have no impact on modification of the production process [3].

2. From concept to design – extensible “wings” baffle and “chain” baffle

Based on the idea to create a baffle that can be used on already existing fuel tanks on the market, took birth the “Extensible Wings Baffle” project. From the conceptual sketch (figure 1) and a general model of a fuel tank & fuel pump module took shape a preliminary model (figure 2).

![Figure 1. Conceptual sketch for Extensible Wings Baffle (baffle integrated on the fuel pump module, where 1/ Upper view of FT, 2/ Module, 3/ Closed baffle position – circular to the module, 4/ Upper view – Baffle during assembly – opening stage, 5/ Baffle in position, 6/ Front view of baffle – section)](image1)

![Figure 2. Fuel tank assembly equipped with fuel pump module and Extensible Wings Baffle](image2)

The main characteristic for this concept is that it can be inserted directly into the fuel tank at the same time with the fuel pump module. For this, the baffle must be wrapped on the pump module (figure 3, 4, 5 – closed position). Once it is inserted in position, the two wings (figure 4) will open to their final position.

![Figure 3. Fuel Pump model](image3)

![Figure 4. Baffle – open Wings](image4)

![Figure 5. Baffle – Closed Wins](image5)

The preliminary design helped understanding the functionality of the concept and highlighted some constructive constrains:
- Presence and movement of the pump module floating device influences the length and shape of the wings;
- Floating device arm movement influences the insertion and locking area of the baffle wings;
- Wings simple structure can present a risk regarding its high flexibility and cannot maintain the open position in function;
- Wings are limited to only two. To solve this constrains a remodeling was done to include some solutions. In figure 6, some of them are displayed:
  - The closing wings system changed so that the wings are closed one on each other by superposition (figure 7). If the floating device was interfering with the wings, applying this solution not only that resolve this problem, but also allows the wings to keep their length (figure 8);
  - The baffle with closed wings and pump module fit directly into the fuel tank hole. The insertion is presented in figure 9 and the final assembly in figure 10.

In order to eliminate the risk generated by the flexibility of the wings it was implemented a material structure improvement by adding some multiple ribs at the base of the wings and on their surface (figure 11).

This solution reduces the flexibility of the wings and has a negative impact for keeping the wings closed on the pump module before the insertion. In this case, the problem will be solved in the manufacturing stage. The baffle will come with opened wings and during the assembly operations, the operator will approach the wings each other to obtain the closed position at the same time with the insertion.

The main characteristics for the extensible wings baffle concept are:
  - Easy insertion for the operator;
  - Simple construction/design;
  - Baffle insertion in the same operation with the fuel pump module;
  - Can be designed and dimensioned for a high variety of fuel tanks that need to improve the slosh noise (already on the market);
- Represents a study base for other technical solutions;
- Does not add extra cost in the manufacturing area;

In addition, the design of this concept highlighted some constructive limitations:
- The movement of the floating device in the fuel pump can limit the construction of the locking area of the wings for some different design of fuel tanks and fuel pumps;
- The wings structure can present some risk in time for maintaining the opened wings position;
- The wings number limited;
- The length of the wings is limited by the fuel pump diameter and can represent a problem for baffle effects in some cases.

Based on the “Extensible wings baffle” concept and on the main research idea – baffle to be used in already existing fuel tanks – a second concept is generated to resolve some of the limitation of the previous concept.

The new concept is based on a construction similar to a chain (figure 12). Depending on the desired length and other characteristics, the number of links (figure 15) of the chain and even the design (figure 14) can be modified. The links (figure 16) are connected to a central support (figure 13) that will be installed on the fuel pump module.
Pushing in the fuel pump module will tension the cable. The cable connects the links of the baffle and connects the two wings. By tensioning this cable, the links will connect into a rigid and fixed position assuring a final position for the Chain Baffle.

General characteristic for Chain Baffle concept are:
- Free and easy insertion into the fuel tank;
- Can be used for a high variety of fuel tanks that need slosh noise reduction;
- Possibility to create a high variation of forms depending of the fuel tank design;
- Multiple wings can be created;

Based on sever analysis for this model, the concept was developed further to improve some raised issues:
- The connection pins only assures connection and have no influence over position and stability;
- The length of the cable needed to permit the chain to be wrapped up to the central support, is too big and after insertion of the fuel pump module will not assure the sufficient tension for the assembly stability;
- Execution for chain links will require precision for the pin locking system and will add additional cost to the product;
- The cable holes in the chain links is too small and creates a risk of breaking during assembly process.

The elements of the baffle (figure 20, 21) were redesigned to permit assembly for another locking pin (figure 22) on a bigger surface. This way can be obtained an improvement for material resistance. The bigger dimensions reduce the manufacturing precision needed and can reduce cost for execution of each of the links. In addition, the spaces between the links were reduced so that the cable length to reduce too. This improves the stability of the chain baffle after assembly due to the connection on a bigger surface. Regarding the cable, to be more effective, the cable support on each link was modified to obtain a more robust contact.

![Figure 20. Connection between central support and chain element](image)

![Figure 21. Detail of the cable connection](image)

![Figure 22. Detail of the chain connection](image)

![Figure 23. Insertion of the chain baffle in the fuel tank](image)

To obtain all of these changes the wrapping up of the baffle chain on its central support had to be partially eliminated. Before the insertion in the fuel tank, there is still a degree of freedom between the links, which has a positive impact in the assembly process for the operator (figure 23, 24, 25).
Conclusion and future work

The 3D models used to highlight the baffle solutions correspond to real dimensions of the fuel pump modules, existent on the current market. Furthermore, the simplified generic 3D model used for fuel tank takes into account the basic dimensions of a serial life fuel tank with a capacity of 50 liters.

The article takes into account the presumption that the technical solutions described above decrease the kinetic energy inside a fuel tank by breaking the waves as much as possible and in the same time, the noise level reduces, too [4]. This hypotheses is going to be confirmed only after static and dynamic numeric calculations and if possible later more by physical tests.

Both extensible baffle and chain baffle are suitable for usage in an already existent fuel tank or serial life fuel tank. While the first efficiency is limited due to the diameter of the module, the second one – the chain baffle can be an alternative that can be adapted as much as possible to the shape of the envelope of the fuel tank. The length of the chain and the possibility to have several chain connections can lead to an increase of efficiency. All this gain in performance of the component has as compromise additional operations on the finishing line of the fuel tank where all the elements are inserted inside. Each additional operation has extra costs, but before choosing a solution it should be prepared a deep analysis that can highlight if the cost generated is worth for a performance issue perceived by the final client – the buyer of the car.

References

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