



A lightweight composite exhaust system for automotive applications

A fiber reinforced plastic composite exhaust system for the automotive market was invented at the chairs of Design and Production of Composite Structures and Systems Engineering & Aircraft Design. TU Delft holds the patent for this invention. As the time comes to bring the concept to life, new challenges arise.

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BACKGROUND

One of the recent inventions by the Faculty of Aerospace Engineering has been a lightweight exhaust system for sport cars made of carbon fiber reinforced plastic. Two students have already done research on this novel concept for the future (see Leonardo Times December 2010). This article focuses on the latest development work that is being carried out in collaboration with Bosal ECS, an exhaust systems engineering and manufacturing company.

WEIGHT IN THE AUTOMOTIVE INDUSTRY

The lightweight composite exhaust system was developed on the basis of two needs from the automotive market: (1) the drive for better performance in sport cars and (2) the necessity of reducing fuel consumption and pollutant emissions.

One of the indices of the overall performance of sport cars is the power to mass ratio. Sport car manufacturers try to maximize this ratio by both decreasing the car mass and increasing the engine power. One of the many advantages from the first solution is the reduced fuel consumption.

Fuel consumption is one of the critical aspects of current thermal engine cars. Automotive emissions contribute about 20% to the overall European CO₂ emissions and are also a major source of pollution in big cities, not to mention economical and political issues arising from the dependence on fossil fuels extracted in foreign countries.

Electric vehicles are one of the solutions to these concerns; however it is well known that in the coming years – and probably decades – oil powered engines will still be used. This is the reason why automotive

equipment suppliers like Bosal continue to invest and do research in this field.

THE COMPOSITE EXHAUST (COMPEX) SYSTEM

Replacing steel ducts with fiber reinforced plastic for 800°C hot exhaust gases is not a good idea, unless a thermal protection system is placed inside the pipe. This is the solution found and what the patent held by the TU Delft is about; it has many advantages, but also many challenges.

The first, and most obvious advantage, is the low weight. Depending on the characteristics of the different thermal protection systems and on the plastic material, savings can range from 30% to 60% of the original exhaust system weight. Additional savings can also be gained by removing or replacing the heat shields that normally surround the hot exhaust pipe. However one interesting side effect comes from

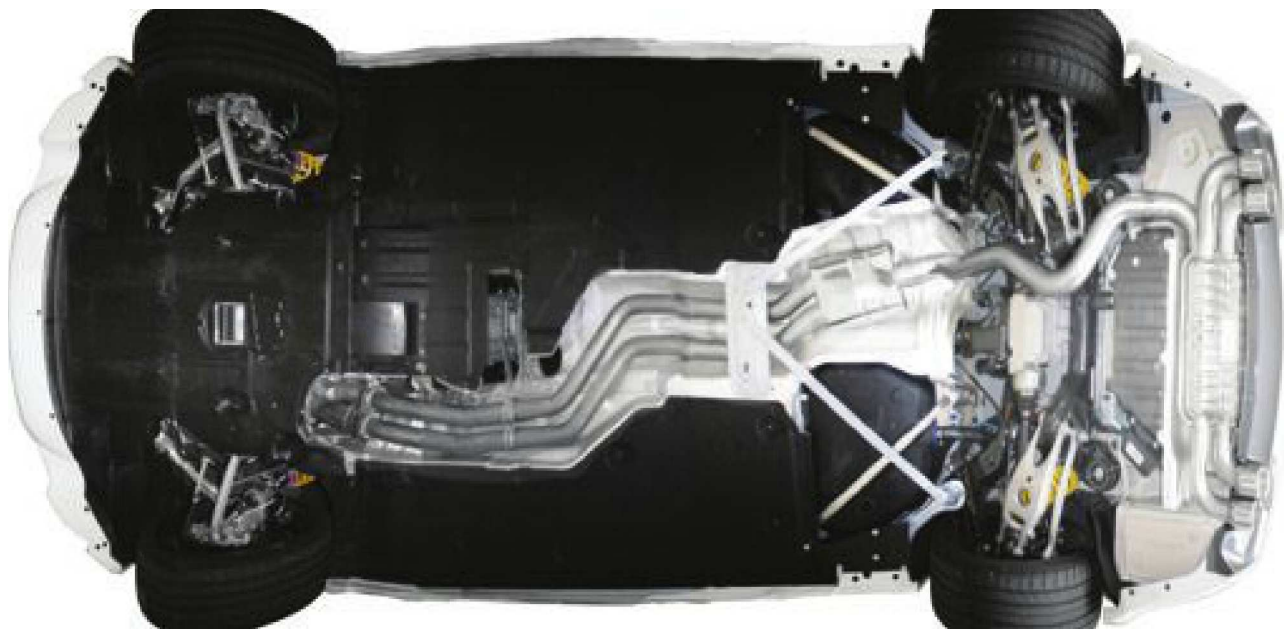


Figure 1. Example of current metal exhaust system. Heavy elements such as the mufflers are integrated in the light weight CompEx pipe.

the difference in sound absorption by the thermal insulating material inside the pipe. This means that the geometry of the exhaust pipe has a greater influence on the sound the car produces, an area which needs more research in the future. But thanks to the ease with which composite materials can be shaped, new exhaust pipe designs and thus car sounds will be possible.

One of the main technical challenges comes from the durability of the composite exhaust system. While the validity of the CompEx concept has been demonstrated on an engine test bench, that is only the starting point for developing a durable exhaust pipe concept, design and system for a real car. Durability mainly involves three families of components: the thermal protection system, the carbon fiber reinforced plastic pipe and the connections between composite and metal pipe.

THE WORK

Designing an exhaust system is a long process which can take years from the start-up of a project until a production line is in place. The current work is focused on three fields: enhancing the durability of the thermal protection system, improving the knowledge about the acoustics of the composite exhaust and making the structural design of the composite pipe. This decision to focus on these areas was driven by the opportunities offered by a collaboration with Bosal, and from the desire to produce a prototype to show to customers in the future.

The most problematic factor in the exhaust pipe was the slow, but constant, erosion of the insulation. In the original design, a coarse metal mesh supports

a thermal insulating blanket – made of short fibers – inside the composite pipe. After running a pipe homologation test of this configuration at the engine test bench, we measured a loss of one fourth to one third of the total insulation material. This means that over time all the insulation would be blown off and the plastic of the pipe directly exposed to the exhaust gases. This was clearly not acceptable. Therefore a new solution needed to be found and tested. Eventually a configuration was found that significantly improved the original design.

The second aspect is the acoustics of the exhaust system. This is a very important matter: some cars must be as silent as possible, while others produce an appealing and characteristic sound. People do not see much of an exhaust system, but they definitely hear it. Since the first impression is what (unfortunately) usually counts the most, the first prototype of an exhaust system must also produce the desired type of sound. Therefore at Bosal, several tests were conducted on the acoustics of the CompEx system. Different configurations of the exhaust system were tested in order to find the volume of sound absorbing material needed, and the best location for it.

Finally – needless to say – a composite exhaust system prototype should be structurally sound. The composite structure is the main contributor to the total exhaust system weight. The weight is an important measure of the success of the composite exhaust pipe and its estimation is important. Composite materials were shown to have a great advantage over metal pipes and cases in many areas including shapeability, tailorability and strength to weight ratio.

COLLABORATION WITH BOSAL EMISSION CONTROL SYSTEMS

Bosal ECS is a multinational supplier of exhaust systems with production plants and research centers located all around the world; they hold about 8% of the worldwide exhaust system market share. Thanks to the networking effort of the department, contact was made and soon a collaboration began which was a great boost for the project. Their support was both material and immaterial. Not only did they provide reassurance that the technology was promising and worth the work, they also contributed knowledge in exhaust systems design and gave access to their testing facilities.

THE LINK BETWEEN AEROSPACE AND THE AUTOMOTIVE INDUSTRY

As an aerospace engineering student, some people may question doing research on an automotive component. Why should the faculty of aerospace engineering support such work? The answer is clear: the aerospace and automotive industry are not two closed worlds with nothing in common. They share the same need for low weight and advanced technologies like fiber reinforced plastic materials. Since the birth of aviation, there has been much technology transfer between these two worlds and the composite exhaust system will soon be another example of this. Previously exclusive aerospace technologies have become products that we use every day. So in a few years, roll under your brand new car and have a look at its composite exhaust system! ✈

References

http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm