Final Report Summary - DESTA (Demonstration of 1st European SOFC Truck APU)

Executive Summary:
On 1st January 2012, the research project DESTA started under the coordination of AVL List GmbH (Austria). The main project objective of the DESTA project was the demonstration of the first European Solid Oxide Fuel Cell (SOFC) Auxiliary Power Unit (APU) on board of a heavy duty truck. By gathering the project partners Eberspächer Climate Control Systems GmbH & Co. KG (Germany), AVL List GmbH (Austria), Volvo Group Trucks Technology (Sweden), Topsoe Fuel Cell (Denmark) and Forschungszentrum Jülich (Germany) into one consortium, a 100% European value chain for a SOFC APU was established. With the aim to reduce pollutant emissions, noise and production costs, the end product shall have excellent export opportunities, creating new job opportunities in the field of high- & clean technology in Europe.

From the start of the project detailed requirements for APU in US type heavy duty truck were defined. In parallel a total of 6 APU systems were tested intensively by Eberspächer and AVL. In this laboratory testing process, total operating hours above 2000 hours, electrical efficiencies of up to 30% and operation on conventional road diesel (ULSD) were demonstrated. Based on the test results the Eberspächer APU was selected for the truck integration. In a parallel exercise TOFC focused on testing of SOFC stacks towards thermal cycle-ability, sulfur tolerance and long term operation. Impressing results have been achieved especially towards thermal cycling with a power degradation of 1.5% over 90 aggressive heat up cycles.

To prepare the truck integration Volvo designed the truck interfaces regarding mechanical, electrical and functional integration. A suitable DC/DC converter was developed to integrate the APU into the electrical grid of the truck. Major efforts were undertaken to develop the control software for operation of the APU within the truck system. Finally the Eberspächer APU was integrated and successfully tested within the truck environment. The truck was tested through regular operating according to US truck usage profiles including driving and idling periods. Truck and integrated APU went through a real life testing cycle including driving and stopping periods through day and night. More than 2,000 km of driving and 50 hours of APU power production during parking were demonstrated.

The final event of the DESTA project was held at Volvo Truck in Gothenburg on 9th of June 2015, assembling the entire project consortium and a representative from the Fuel Cells and Hydrogen Joint Undertaking. At this event, the 1st European SOFC Truck APU was successfully demonstrated. With this electrical net power class of 3 kW, the world premiere of a diesel-operated SOFC APU on board of a heavy duty truck could successfully be presented. The project was then finished on June 30th 2015 and has reached every major target.

The SOFC APU technology developed within the DESTA project definitely shows great potential to reduce anti-idling pollutant emissions and costs for fuel consumption of heavy duty trucks. The technology also improves the driver's comfort and has a positive impact on the surrounding environment due to a dramatic reduction of noise. Detailed cost analysis has also shown economic potential, however further measures have to be undertaken to bring this technology into the marketplace.

Project Context and Objectives:

Idling of heavy duty trucks is a major concern within the industry. Typical US heavy duty trucks are idled up to 8hrs per day especially during over-night stays on parking lots. During these breaks the driver consumes electric energy for various comfort functions like A/C, radio, TV & micro oven. Today this power demand is provided by idling of the main engine or by
conventional engine based APU systems. Both solutions are not very efficient, emit a significant amount of emissions and produce major noise. Also economically idling especially with the main engine is quite expensive due to an idling fuel consumption of around 2.5-3L/h. Due to the raising concerns various US states (Figure 3) have implemented idling regulations which more or less prohibit or at least limit idling of engines. Under discussion is at the moment a complete US wide idling ban which would significantly boost the sales of anti-idling solutions. Based on all these boundary conditions AVL and Eberspächer already decided years ago to develop SOFC based APU systems for heavy duty trucks, which have partnered in the DESTA project to accelerate the development of SOFC APU systems.

Motivation for SOFC based APU systems:
- Anti idling regulations
- Fuel cost savings
- CO2 credits
- low noise
- 5min idling ban

The main objectives of the DESTA project were:
- 1 year thorough testing of SOFC APU prototypes from AVL and Eberspächer
- Development and assembly of the final DESTA SOFC APU system, merging the most promising approaches of AVL and Eberspächer SOFC APU concepts
- Off-vehicle tests of the final DESTA SOFC APU system regarding durability as well as reliability assessment under harsh operating conditions (e.g. vibration, salt spray)
- Long-term accelerated test of the final DESTA SOFC APU systems to assess the lifetime potential
- Truck integration and demonstration of a DESTA SOFC APU system on-board of a Volvo US type heavy duty truck

The project also defined very detailed technical objectives for APU systems to be demonstrated within the DESTA project:
- Maximum electrical power ≥3kW
- Operation on conventional road diesel fuel (< 15 ppm S)
- Long-term tests: ~ 300 thermal cycles and ~ 3.000 operating hours
- System electrical net efficiency around 35%
- System volume and weight below 150 l and 120 kg
- CO2 reduction of 75% compared to engine idling of a heavy-duty truck
- Start-up time of ~30min
- Noise level ~65dB(A)
- Completely functional truck integration

Project Results:
Please take the description from the report enclosed, since it is not possible to enter figures or tables here.

Potential Impact:
Potential impact
After the successful demonstration of a SOFC APU on a heavy duty truck, it has been proven that the technology is mature enough to function as an on board power source for the anti-idling use case during a typical long-haul transport mission. It has also been demonstrated that there is a great fuel saving potential with an SOFC APU compared with an idling truck engine. The fuel savings could result in cost savings for the vehicle owner as well as reduced CO2 emissions. For the truck owners perspective the anti-engine idling will also reduce engine hours, engine maintenance and service cost. Even though not quantified in vehicle, the environmental impact could most probably also be lowered since there are very little emissions of NOx and particles from the SOFC APU compared with a truck engine or diesel generator APUs. Using an SOFC APU will have driver comfort benefits since it is vibration free, but also reduced noise levels (~58dBA) compared to an engine or diesel generator APU which is a great benefit for the driver as well as the surroundings of the parked truck.
However, the higher production costs are a very great challenge at the moment. The main cost driver is the fuel cell. Moreover, the cost projections of truck manufacturers are very ambitious.

Exploitation of results
The successful achievement of most of the DESTA targets provides a good baseline for further exploitation of the results. Nevertheless, the project showed also some existing bottlenecks especially towards the addressed application of heavy duty trucks.

The exploitation plan includes:
• The market potential and addressable market have been in depth analyzed within the DESTA project by AVL and Eberspächer. SOFC APUs represent an improved product for an existing market. The existing market of truck APUs only in US represents a sales volume of about 50.000 units per year. The existing products are based on small diesel engines and battery based solutions. Absolutely dominant market leader in this field is ThermoKing.
• Dissemination of the DESTA achievements with the truck industry in US and EU (including OEMs and large fleet operators)
• Preparation of additional demonstration projects with truck OEMs and fleet operators to raise the awareness for this technology at critical decision makers
• Further analyses of the business case compared to existing solutions and updated by regulatory changes for anti-idling.
• Continuation of the development to improve key performance indicators and reduce cost:
  o Improve the efficiency to around 40%
  o Improve the robustness and lifetime to 5.000hrs
  o Further reduce the system cost by DtC and DtM measures
  o Investigate the application of new metal-supported SOFC stack technology which offers a significantly reduced cost potential than in DESTA used ASC technology.
  o Reduce the start-up time to below 45min by system improvements and/or alternative stack technology (MSC)
• Dissemination of the results to policy makers (e.g. Department of Energy, US) to show the CO2 reduction potential of this technology and to elaborate tax credit incentives and CO2 bonus systems to support market introduction.
• Investigation of early markets for this technology like special purpose vehicles. This vehicle category is not as cost sensitive as the commercial heavy duty truck industry and therefore market entry is much easier and bears less risk. Successful roll-out of a commercial product in this market will also accelerate the heavy duty mass-market. Discussions with first OEMs have already been started and especially AVL is performing at the moment >5 demonstration projects within this market segment.
• The consortium believes that a commercial product for special purpose vehicles might be available in the timeframe 2017-18. Depending on market entry support (CO2 credit system, tax incentive system,....) commercial roll-out to the heavy duty truck market might start in the timeframe 2018-2020.
• Evaluate the possibility to place a larger field-test of APU systems installed in heavy duty trucks and/or busses under the FCH JU 2.
• Investigation of smaller APU systems (<2kW) with OEMs for the US and European market for anti-idling and night-city logistic vehicles.
• Due to the successful demonstration and prove of concept of the SOFC APU Volvo will start to develop technology road maps for future fuel cell activities. Volvo will also in closely monitor any other technology improvements within the fuel cell area.
• For a market introduction of a SOFC APU and acceptance of the end customer, the investment cost is of great importance and Volvo is following this in order to evaluate the business case.
• The clean and efficient performance of the SOFC fuel cell APU as an on-board electric power source is a technology that might be of interest for other applications than an APU for anti-idling.
• The results of the DESTA project will be disseminated internally within Volvo to managers, product planning and engineers to spread the results and transfer technology know-how to increase the awareness of the state of art technology and facilitate future initiatives within the fuel cell area.

A table of main dissemination activities is featured in the public report enclosed.
Related information

**Result In Brief**
Novel auxiliary power units to mitigate negative consequences of idling heavy duty trucks

**Documents and Publications**
final1-278899_desta_final-publishable-summary-report_final-corrected.pdf

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