PRESS RELEASE

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Additively manufactured rocket engine features an aerospike nozzle for microlaunchers

(Dresden, March 22, 2021) Microlaunchers are an alternative to conventional launch vehicles. Able to carry payloads of up to 350 kilograms, these midsized transport systems are designed to launch small satellites into space. Researchers at the Fraunhofer Institute for Material and Beam Technology IWS in Dresden and TU Dresden's aerospace experts developed an additively manufactured rocket engine with an aerospike nozzle for microlaunchers. The scaled metal prototype is expected to consume 30 percent less fuel than conventional engines. It will be presented at the "Hannover Messe 2021 Digital Edition" from April 12 through 16, 2021.

The market for small satellites is sure to boom in the years ahead. The United Kingdom aims to build a spaceport in the north of Scotland, the first on European soil. The Federation of German Industries (BDI) has also endorsed the idea of a national space-port. It is to serve as the pad for small-to-midsized launchers that haul research instruments and small satellites into space. These microlaunchers are engineered to carry a payload of up to 350 kilograms. Aerospike engines are an efficient means of powering these microlaunchers. They offer the welcome prospects of far less mass and far lower fuel consumption. Over the last three years, a Fraunhofer IWS research team together with the Institute of Aerospace Engineering at TU Dresden has developed, manufactured and tested such an aerospike engine in various design iterations. Both the German Federal Ministry of Education and Research (BMBF) and the European Space Agency (ESA) are funding the project. What sets this aerospike engine apart from others is that its fuel injector, combustion chamber and nozzle are printed layer by layer in an additive manufacturing process called laser powder bed fusion (L-PBF). The nozzle consists of a spike-like center-body designed to accelerate combustion gases.

"The technology behind aerospike engines dates back to the 1960s. However, only the geometric freedom offered by additive manufacturing, in combination with conventional finishing processes, allows us to produce such efficient engines at all", emphasizes Samira Gruber, scientific assistant at the Additive Manufacturing Center Dresden (AMCD), which is jointly operated by Fraunhofer IWS and TU Dresden. Aerospike rocket engines promise fuel savings of around 30 percent over conventional rockets. They are also more compact than conventional systems, which reduces the overall system's mass. "In spaceflight, every gram saved on the engine results in either

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less fuel needed to get into orbit or more payload that can be transported," explains Lukas Stepien, Group Manager Powder Bed Processes and Printing at Fraunhofer IWS. The aerospike nozzle developed by Fraunhofer IWS and TU Dresden better adapts to the changing pressure on the trip from Earth to orbit. This makes it more efficient, so it burns less fuel than conventional engines.

An additively manufactured nozzle with near-contour cooling

“We opted for an additive way of manufacturing the metal rocket because the engine requires very good cooling and needs internal cooling channels. This complex regenerative cooling system with labyrinthine internal ducts cannot be milled or cast in conventional ways,” says Stepien. Applied layer by layer, the powder is then melted. This selective laser melting gradually builds a component with one-millimeter-wide cooling channels that follow the combustion chamber’s contours. Residual powder in the channels is then vacuumed out completely. This metal has to hold up to rigorous demands, remaining solid at high temperatures and conducting heat well to ensure optimum cooling. “Temperatures in the combustion chamber are above the melting point of many metals, so active cooling is required," explains Samira Gruber.

Scientists at Fraunhofer IWS and TU Dresden are looking to the injection system in a bid to further boost engine efficiency. Called CFDµSAT, this project has been underway since January 2020 with the Ariane Group and Siemens AG taking part as associated partners. Injectors pose major design and manufacturing challenges. “Fuels first serve to cool the engine. They heat up and are then induced into the combustion chamber. Liquid oxygen and ethanol are added separately to be blended via an injector. The resulting gas mixture is ignited. It expands in the combustion chamber and then flows through a gap in the combustion chamber to be decompressed and accelerated by the nozzle,” notes Gruber, explaining how this engine produces thrust.

Engine hot-fire test

The Dresden-based researchers have already tested the prototype of the aerospike engine in a test cell at TU Dresden’s Institute of Aerospace Engineering, achieving a burn time of 30 seconds. “So far, there have been few hot -fire tests of aerospike nozzles," Gruber says. "We have proven that additive manufacturing can be applied to produce a working liquid propellant jet engine, and in a follow-on project funded by ESA, we will now redesign and manufacture another aerospike engine and also test this one."

The advancement of the aerospike topic is one example of the close cooperation between TU Dresden and non-university research institutions within a science cluster called the DRESDEN-concept. TU Dresden is responsible for the engine's design and layout; Fraunhofer IWS for the manufacturing and material validation. Their first step was to adapt the design to the additive manufacturing process. The researchers then selected and characterized the material. Next, they produced the engine's two components with the L-PBF method and reworked their functional surfaces. The components were joined by laser welding and a computed tomography scanner inspected for pores and other defects. This non-destructive evaluation can also determine if sintered powder is obstructing the cooling channels. This project demonstrates how AM processes can be integrated into today's process chains in a productive way across all industries to advance the state of the art in manufacturing.

A design demonstrator for an additively manufactured aerospike nozzle
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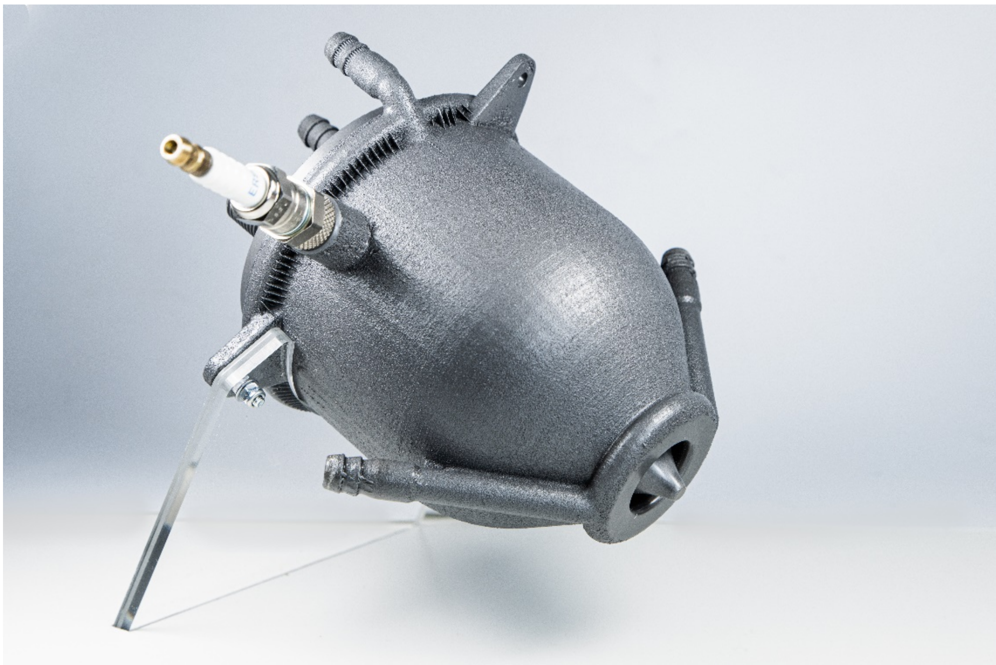
At Westsächsische Hochschule Zwickau, IWS runs the Fraunhofer Application Center for Optical Metrology and Surface Technologies AZOM. The Fraunhofer project group at the Dortmunder OberflächenCentrum DOC® is also integrated into the Dresden Institute. The main cooperation partners in the USA include the Center for Coatings and Diamond Technologies (CCD) at Michigan State University in East Lansing and the Center for Laser Applications (CLA) in Plymouth, Michigan. Fraunhofer IWS employs around 450 people at its headquarters in Dresden.



This prototype of the aerospike engine has already been tested by the Dresden researchers on the test stand of TU Dresden.
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