ESA TECHNOLOGY BROKER DEUTSCHLAND

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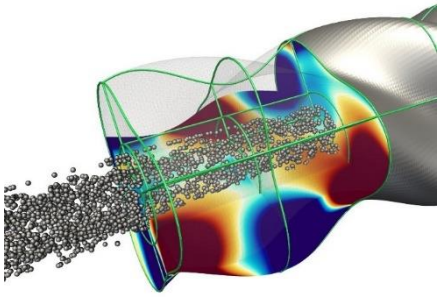
Category: **Sensoren und Messtechnik**
Reference: **TD250**

Simulation of plasma dynamics and electromagnetics

Description:



The service to be offered is based on the simulation software PICLas and the expertise of the founders in the numerical simulation of plasma dynamics. The three-dimensional software PICLas, developed cooperatively by the Institute of Space Systems and Institute of Aerodynamics and Gas Dynamics at the University of Stuttgart, utilizes particle-based numerical methods and a high-order field solver to enable the simulation of rarefied gas and plasma flows under the influence of electromagnetic forces. The software was successfully applied to the simulation of atmospheric entry manoeuvres, electric propulsion systems and satellite communication components (travelling wave tubes).
Many terrestrial high-tech processes utilizing vacuum conditions, plasma as well as laser-plasma interactions are not well understood. Through the numerical simulations offered by the company, vacuum coating companies and semiconductor manufacturers using these processes shall gain insight into the physical details and thus improve product development and optimize working parameters of their facilities. The services shall thus enable time and cost savings by reducing the number of required test campaigns and prototypes. The three founders behind the company have gathered experience in rarefied gas and plasma dynamics during their studies of aerospace engineering and their subsequent PhD work at the University of Stuttgart, where they were an integral part of the development of PICLas. This allows them to efficiently use PICLas and perform necessary extensions for applications outside the space sector.

Innovative Aspects:

Conventional computational fluid dynamics have difficulties to simulate rarefied gas and plasma flows under strong thermal and chemical non-equilibrium, especially under the influence of electromagnetic forces. The innovative approach of PICLas is the coupling of two well-established particle methods, Particle-in-Cell and Direct Simulation Monte Carlo. While the former is used to simulate the interaction between charged particles and electromagnetic forces in free molecular flow, the latter is used to model rarefied gas flows including the exchange of internal energies and chemical reactions. Both methods have been verified and validated for a multitude of applications such as atmospheric entry, electric propulsion systems, gyrotrons, and travelling wave tubes. The advantages over other computational tools have been demonstrated, based on e.g. simulations of a 140 GHz gyrotron, where PICLas was able to reproduce the expected operating frequency, while a commercially available tool failed to do so.
With the increasing affordability of computational resources, an additional advantage is the strong focus on the optimization of PICLas for high-performance computing with a parallel efficiency of over 90% on up to 12 000 cores for certain cases. This allows the code to be utilized for complex, three-dimensional problems (e.g. the interaction of several thrusters of an electric propulsion system or the complete vacuum coating facility) with a reasonable computational demand.

Finally, the service of the technology owner allows other companies to focus on their main business and benefit from modern numerical simulation technologies without large upfront investments. Detailed physical insight provided by numerical simulations can support development of innovative products, help find optimal working parameters to reduce the downtime of production facilities and limit the number of prototypes and test runs to a few.

Application Areas:

Current: Atmospheric entry manoeuvres, electric propulsion systems, travelling wave tubes, gyrotrons, laser-plasma interaction
Potential: Vacuum surface coating, semiconductor manufacturing, high-frequency engineering, nano- and microsystems

Cooperation:

- Industrial companies, whose processes include vacuum, plasma dynamics or laser-plasma interaction
- These could be semiconductor manufacturers and companies that are developing and/or utilizing vacuum surface coating technologies, high-frequency components such as gyrotrons and travelling wave tubes, and nano- and microsystems
- The technology owner would perform numerical simulations of the respective processes to enable the partner to optimize working parameters, improve the development of novel products and gather detailed insight in the physics

Space Heritage:

The Institute of Space Systems at the University of Stuttgart develops novel electric propulsion systems and operates several plasma wind tunnels investigating high temperature measurements techniques for the development of heat shield materials. To support these activities, the multi-purpose software tool PICLas was developed in cooperation with the Institute of Aerodynamics and Gas Dynamics to enable the numerical simulation of rarefied gas and plasma flows including electromagnetic interaction. The conditions prevalent in the space environment during e.g. atmospheric entry manoeuvres and the operation of electric thrusters, required the development and implementation of numerical methods beyond the capabilities of conventional computational fluid dynamics software. The development was supported financially by the German Research Foundation (DFG) and industry partners from the space sector.