 Proceedings of ICCES'08, pp.380-380

Shape Optimization of Herschel Small Nozzles to Decrease a Plume Divergence

G. Markelov[1], J. Kroeker[2]

Herschel satellite uses Helium II to cool scientific instruments down to temperatures of 0.3 K. The Helium is continuously released during the entire mission by small nozzles. These small nozzles create a counter-torque which used to compensate torque caused by the solar pressure acting on satellite surfaces. The design of the nozzles shall minimize the plume impingement. A mass flow rate through the nozzle is very small and, as a result, a gas flow inside the nozzle is in transitional flow regime. In this case friction force plays much more important role than it does in a continuum flow regime. This leads, for example, to a formation of rather thick boundary layer and wider plume and an optimal nozzle shape will differ from a shape obtained for larger mass flow rate. Moreover, a continuum approach (Navier-Stokes equations), is not valid any longer and a kinetic approach has to be applied to model a flow inside the nozzle and plume flow. An optimization of a nozzle shape for viscous flow is not well studied despite that this has became rather popular topic due to coming miniaturization of satellites. By now there are a limited number of publications dedicated to an increase of the nozzle performance in transitional flow regime and nothing about a nozzle optimization towards to a smaller plume divergence.

A numerical analysis showed that the initial design of the Herschel small nozzles created a wider plume than it was anticipated. This leads to plume impingent and creation of disturbing forces and moments that can decrease a life-time of the Herschel satellite significantly.

The paper presents a numerical analysis of nozzle and plume flows aimed to shape optimization of the nozzles and decrease of the plume divergence. The computations were performed with a kinetic approach (the direct simulation Monte Carlo method) for different shapes of subsonic and supersonic nozzle parts taking into account restrictions on the nozzle geometry. For example, nozzle length and diameter can not be larger than 25 and 15 mm, respectively. It was shown that a half-angle of the supersonic part affects the plume divergence more significant than other key parameters: shape of the subsonic part, throat, expansion ratio, and nozzle lip. As a result of computational analysis, the nozzle shape has been chosen and manufacturing and experimental testing of the new nozzles are going on.

[1]AOES Group BV, Postbus 342, 2300 AH Leiden, the Netherlands
[2]EADS Astrium GmbH, Friedrichshafen, Germany