SIROM

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PUBLIC NOTE FOR H2020 SIROM, D1.4.

1. INTRODUCTION

SIROM project aims to develop a key component for future space robotics and realize a first-of-its-kind standard, multi-functional intelligent interface (IF) for space robotics between APMs in both orbital and planetary environments. The project is very ambitious and its positive outcome will have strong impacts in the next few generations of spacecrafts. The project will also intend to build on the impact to space robotics within consortium and expand this potential impacts to other players in robotics beyond the consortium. For this reason the consortium is very proud of the project and will do its best to disseminate the results to the widest audience.

SIROM project consortium consists of the following partners:

- SENER Ingeniería y Sistemas S.A. SPAIN
- AIRBUS Defence & Space. UNITED KINGDOM
- AIRBUS DS GmbH. GERMANY
- Thales Alenia Space. ITALY
- Leonardo ITALY
- University of Strathclyde. UNITED KINGDOM
- Deutsches Forschungszentrum für Künstliche Intelligenz. GERMANY
- TELETEL. GREECE
- Space Applications Services. BELGIUM
- MAG SOAR SL. SPAIN

This report provides a brief introduction to the research work undertaken on Multidisciplinary design and modelling of a SIROM concept.

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2. SIROM VISION AND CONCPETUAL DESIGN APPROACH

SIROM's vision for the future is to provide a European capability able to achieve cost savings and higher operational flexibility for spacecraft orbital missions and planetary robotic systems. It is intended to operate SIROM standard interfaces and active payload modules in a broad range of space environments and missions from LEO to GEO and on different planetary surfaces. These aims are driven by the demand for global communication, mobility, safety, environmental monitoring and social developments the number of in-orbit space elements, spacecraft increases rapidly. The realizisation of a standardized modular interface and an active payload module constitute a decisive building block within this development strategy, therefore the aim is to develop standard IFs for orbital and planetary scenarios. Some of the key innovations to be developed in SIROM include a proposed standard to use for power transfer and data transmission for both planetary and orbital space robotic missions and methods for thermal conduction and management. Holistic consideration of many design parameters are done by using multi-criteria design optimization of many conflict requirements through modelling, multi-physics simulation and optimization. The purpose of the multidisciplinary design and modelling is to produce a proof of concepts of the IF, to develop ideas, to fix certain parameters, and to explore design ideas. Modelling work has been undertaken at component level, focusing on developing common components with associated simulation models in order to generate automatically simulation models. There are strict restrictions on the size the connectors must be (150 x 150 x 150 mm3) and a required thermal load of 150 W to be transferred.

(Left to right) Overview of the preliminary engagement, and one side of the connector.

The geometry for the simulations was simplified by removing the data connections, power pin and part of the crown to leave the surface interface with only the main components of thermal and mechanical interest.

2.1 Thermal design consideration

In the simulations heat was transferred through conductive ports which transfer heat from one IF to another only by passive elements, e.g. heat pipe. The geometry was simulated as a mated connector allowing for the initial conditions of each side. The material chosen for the connector interfaces in the simulations was an Aluminium alloy 7050 (Copper: Young modulus: 110 GPa, Heat capacity (at constant pressure): 385 J/kgK, Density 8960 Kg/m3, Thermal conductivity: 4000 W/mK along Z). The heat pipe pin was not modelled internally so in order to exhibit its characteristic behaviour the conductivity of the copper material was changed accordingly to emulate the elevated conductivity of a heat pipe compared to that of a normal copper rod and were modelled to exhibit anisotropic thermal conductivity behaviour with elevated conductivity along z. Some assumptions were made; the heat distribution pins are a perfect constant heat source, there may be some thermal conduction out to the cold payload side.

Parameters; External ambient temperature range: -120oC to +120oC, Heat pins dissipate 150 W between 4 on the hot side, Ambient pressure: 1x10-8 Pa (LEO), Ambient humidity: 0, Ambient wind velocity: 0 ms-1, Ambient solar irradiance: 0 Wm-2, 'hot' side initial temperature: 25oC, 'cold' side initial temperature: 0oC, Contact pressure: 100kPa, Microhardness: 3GPa, Surface

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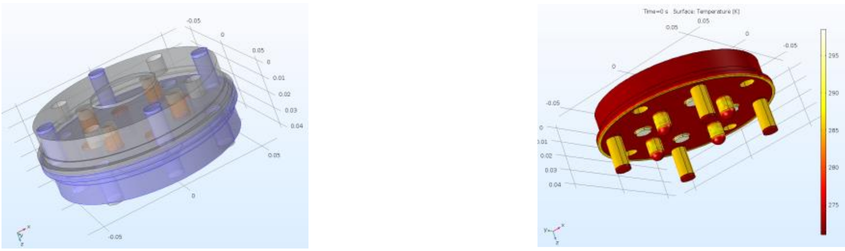
roughness asperities average height: 1µm, Asperities average slop: 0.4, Strain reference temperature for thermal expansion: hot side 25oC, cold side 0oC. Time given for heat transfer; 60 seconds.

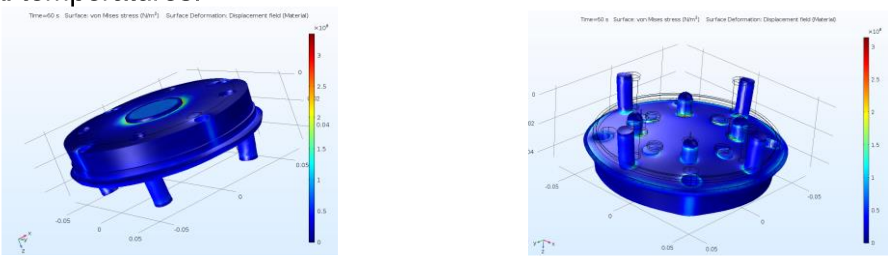


(Left to right) Examples of the simplified modelling geometry of one side of the connector and mated connector sides.

Results summary

A preliminary analytical model has been set up and solved to give the temperature gradients and thermal stresses across the connector sides. Maximum temperature on a given surface (after heat transfer for 60s): 311K [Hot side in +120oC], Minimum temperature on a given surface (after heat transfer for 60s): 275K [Cold side in -120oC], Maximum thermal stress: 5 x 107 N/m2 [Cold side in -120oC], Minimum thermal stress: < 0.5 x 108 N/m2 [Both sides in both environments].

The stresses and deformation of the connector were analysed internally and externally. The simulation is modelled from a point, in time, in which the mating side is already warm and there is heat transfer between the sides of the connectors. The initial mating of the connector was modelled to illustrate any deformation and stresses caused by the mating of the two sides with different initial temperatures.



Examples of thermal stresses & deformation of the connector sides. (Deformations scaled up by factor of 240 to exaggerate displacement).

2.2 Mechanical design and modelling

The mechanics of the IF has been simulated with ANSYS in order to validate its geometry and to assess the load it is capable of handling. A preliminary analytical model has been set up and solved to give dimensions to the bearing load parts. Launch loads are not taken into account at this stage of the project.

Parameters

Material; Aluminium Alloy material (Young modulus: 71 GPa, Yield Strength: 310 MPa, Density 2770 Kg/m3). A torque of 1000 Nm and an axial force of 400 N have been applied to upper interface, lower surface of the other has been constrained.

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Results summary

Maximum flexural stress at the base of the lamina: 262MPa; Axial stress/strain of the SMA wire: 550MPa/8.45%; Number of wires: 4; Maximum Torque: 1.000 Nm; Maximum axial force: 400 N; Maximum radial translation force: 21.000 N.

(Left to right) Loaded ANSYS model, deformed shape due to the only torque and total deformation of loaded latched interfaces.

The simulations were conducted as a pre-preliminary design stage therefore the known parameters and boundary condition at this stage of the project were limited, therefore accomplished assumptions and simplifications have been made. The work demonstrates a possible design of the IF, tackles some main issues related to the layup and to the mechanical and thermal functionalities, and shows how shapes deform during the operations. More importantly, the multidisciplinary simulation illustrates a methodology that can be successfully applied at a more detailed stage the design.

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