Appendix T

THERM3D / e-Therm GMM (conductive) and TMM generation of thermo-mechanical antenna support designed for ALM

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Abstract

Additive Layer Manufacturing (ALM) becomes more and more in the wave of spacecraft pieces manufacturing (i.e. antenna support). Experiences in aeronautics and medical implants bring opportunities for innovation, lower costs and make ALM a modern fabrication process. However, 3D printing needs 3D models that fit mechanical and thermal constraints. The main objective is to converge to a single model iterating through CAD, mechanical and thermal expertises. CAD constraints evolved from classical manufacturing to ALM by increasing the complexity of CAD model, not in the size but by the use of a complex mix of shapes largely depending on B-Spline surfaces, extrusions and cuts.

For the thermal point of view, and as the 3D conduction optimisation always depends on material characteristics, fluxes direction, shape optimisation, the thermal expert is still needed for such calculation and a push-button CAD software is not sufficient. For these reasons, THALES ALENIA SPACE (TAS) decided to improve the actual existing 3D conductive session within e-Therm in order to provide CAD import, meshing facilities, automated nodal breakdown that fit ALM constraints. In this presentation we would discuss about TAS needs and progress on ALM design for thermal analysis, the actual THERM3D research and development that has been integrated into e-Them since 2007, but also how DOREA solved major technical issues on importing raw CAD models for meshing to finally conductivity calculation and temperatures cartography. We will show in this presentation an example on an antenna support but is also used for heat-pipe 3D section modelling.
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   • Application process (CAD import / surfacic meshing generation, volumic meshing generation, automated nodal breakdown generation, TMM generation, results)
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Introduction - Context

- Additive Layer Manufacturing (ALM) becomes more and more in the wave of spacecraft pieces manufacturing
- 3D printing needs 3D models that fit mechanical and thermal constraints
- TAS decided to improve the actual existing 3D conductive session within e-Therm, in order to provide CAD import, meshing facilities (both surfacic and volumic), automated nodes split that fit ALM constraints
- DOREA solved major technical issues on importing raw CAD models for meshing to finally conductivity calculation and temperatures cartography
- Presentation will focus on application requirement (ALM antenna support), technical issues to solve, THERM3D improvement, application process

E-Therm 2.0 – New Functionalities

- Data Base: Information on nodes, on exchanges and on heater lines
- Graphical Post Processing
E-Therm 2.0 – New Functionalities

- Porting e-Therm to 64 bits platform: upgrade of all open-source libraries
- 3D Conductive Session:
  - Import CAD model (STEP AP203/214)
  - Automated Surface and Volumic meshing: NetGen or GMSH (open source meshers) Automated 3D Nodal Breakdown
  - Facilities to affect thermo physical and optical properties: Affectation of material files directly on the CAD shape
  - Results:
    - Cartography of temperatures
    - Determination of equivalent conductive exchanges on kept nodes (elimination of other nodes and vertices temperatures recovery using FEM algorithm)

Application requirement (GMM and TMM generation of thermo-mechanical antenna support designed for ALM)

- ALM Techniques for Space Items
  - Possible complex geometries: from simple geometric volumes to "organic" shapes
  - Optimized shape for performance purpose: mechanical, thermal, mass, manufacturing process... and cost

- eTherm development for Thermal performance characterization/validation
  - CAD model import in the Thermal suite Interface and surfacic/volumic Thermal Meshing
  - Reduced Nodal distribution mapping and materials selection
  - Conductor matrix calculation (TAS heritage Equivalent method: Therm3D)
  - Temperature resolution, cartography analysis

- Use Case: an antenna support
  - Selected for amazing geometry
  - Designs mainly for mechanical purpose
  - No link to external environment, internal Radiation neglected, may produce low equivalent conductive coupling... but not too much
**Basic Principles of THERM3D**

- **Base**: TAS-F EQUIVAL reduction method applied to a FEA model
- **Use**: Use of a classical FEA GMM with 3D and 2D meshes on the surface to constitute the final nodal model
- **Core algorithm**: Core algorithm: automated reduction of the FEA model into the final nodal model and Elimination of 3D meshes: Generation of an equivalent conductive matrix in Equivale form
- **To be integrated**: To be integrated in the final system level model with the rest of the TMM (radiative, power, MC)
- **Option**: Option: automated recalculation of temperature on FEA vertices (within the surface and the volume)
- **Thermal results**: Thermal results on the classical TLP (nodal) model

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**e-Therm**

thermal model generation for ALM application

**CAD import**:
Surfacic meshing generation (15000 triangles, 15 min.)

Save the attachment to disk or (double) click on the picture to run the movie.
Conclusion - Perspectives

**Conclusion:**

- Major issues due to complex CAD geometry have been solved in this first step
  - Ability to create semi-automatic nodal breakdown directly from CAD model
  - The full process duration is optimized and process is used within industrial program in TAS Cannes
- Other application: study of the heat pipe profile for the characterization of the conductance between fluid and sole
  - Function able to calculate surface of contact between fluid and grooves for example

**Perspectives:**

- A major improvement is to implement the radiative geometry model reduction for TMM integration, derived from the CAD model (reduced from 15,000 faces to 150 faces)
- Development of post processing module able to compare automatically RTMM results with initial FEM temperatures calculation at vertices for nodal breakdown validation
- Due to the good performances, e-Therm / THERM3D can be envisaged for ALM shapes topologic mechanical / thermal optimization

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