

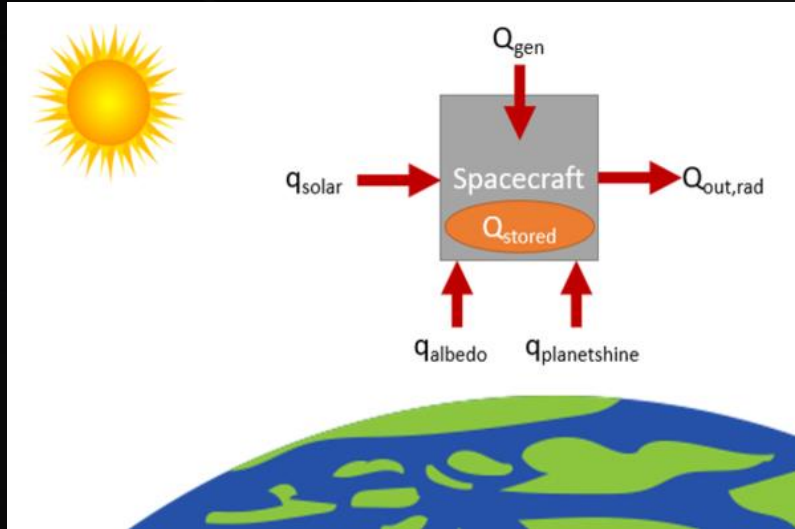
Thermal Control of Spacecraft Under Uneven Heating Environments

Irene Jingqi Ou

Shenzhen Middle School China

Introduction

Solar environment



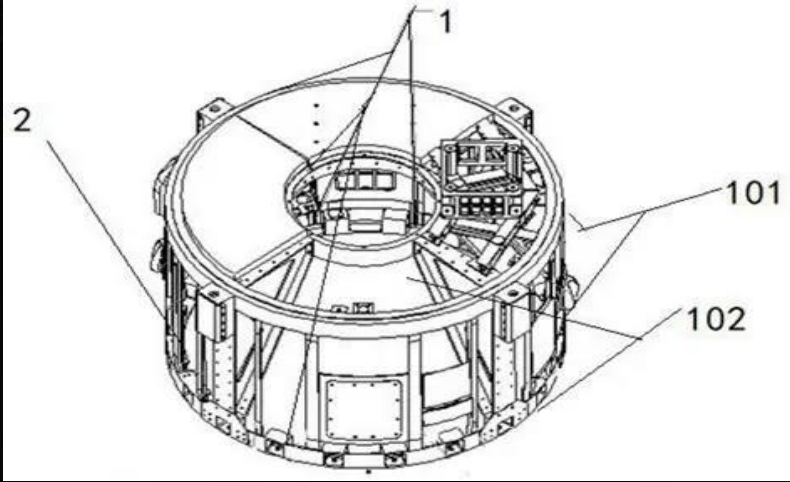
Deep space is near-vacuum, and convective heat transfer does not exist.

Spacecraft exchanges heat by thermal radiation and internal thermal conduction.

Uneven solar radiation creates huge temperature differences in the body, which induce thermal deformation.

Introduction

Problematic effects



Structural mechanical risk

Large accumulated thermal expansion and deformation can damage the structure/shape of the spacecraft.



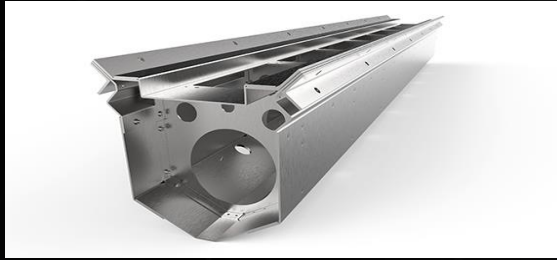
Decrease in accuracy of components

Even tiny displacements affect operation of high-precision instruments.

Potential Solutions

Widely implemented methods

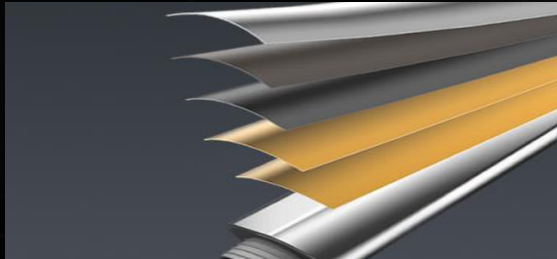
1 Base metal



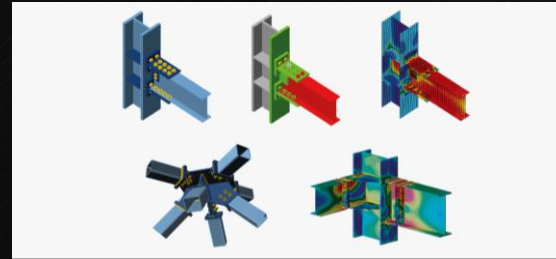
2 Conductive insert



3 Coating shield



4 Structural design



Potential Solutions

Where comes the effectiveness



01 Reduce total expansion

- Select base metals with low thermal-expansion coefficient
- Reduce heat absorption by reflective coatings

03 Optimize configuration

- Adjust number of conductive inserts
- Change insert axial position for better performance

Why?

02 Increase uniformity

- Adopt base material with higher thermal conductivity
- Place high-conductivity inserts to promote conduction

04 Reduce heat absorption

- Apply well-matched reflective surface coatings
- Reduce surface solar absorptivity

Potential Solutions

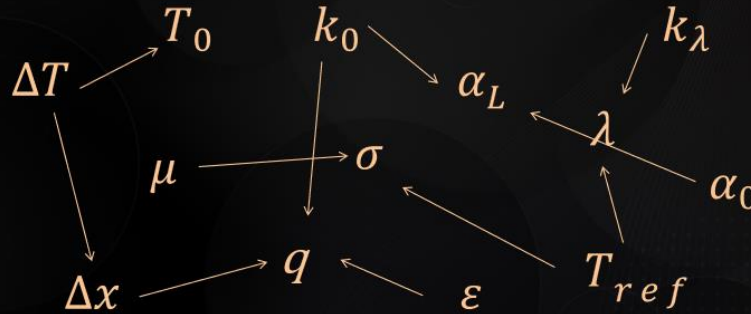
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Computation As A Solution

Why use computation



1. Analytical solutions are difficult to find due to complicated nonlinearity.
2. Numerical computation provides a unified evaluation framework, enabling fair side-by-side comparison.
3. Numerical calculation evaluates physical quantities at discrete spatial points, supporting visualisation.

5 mins

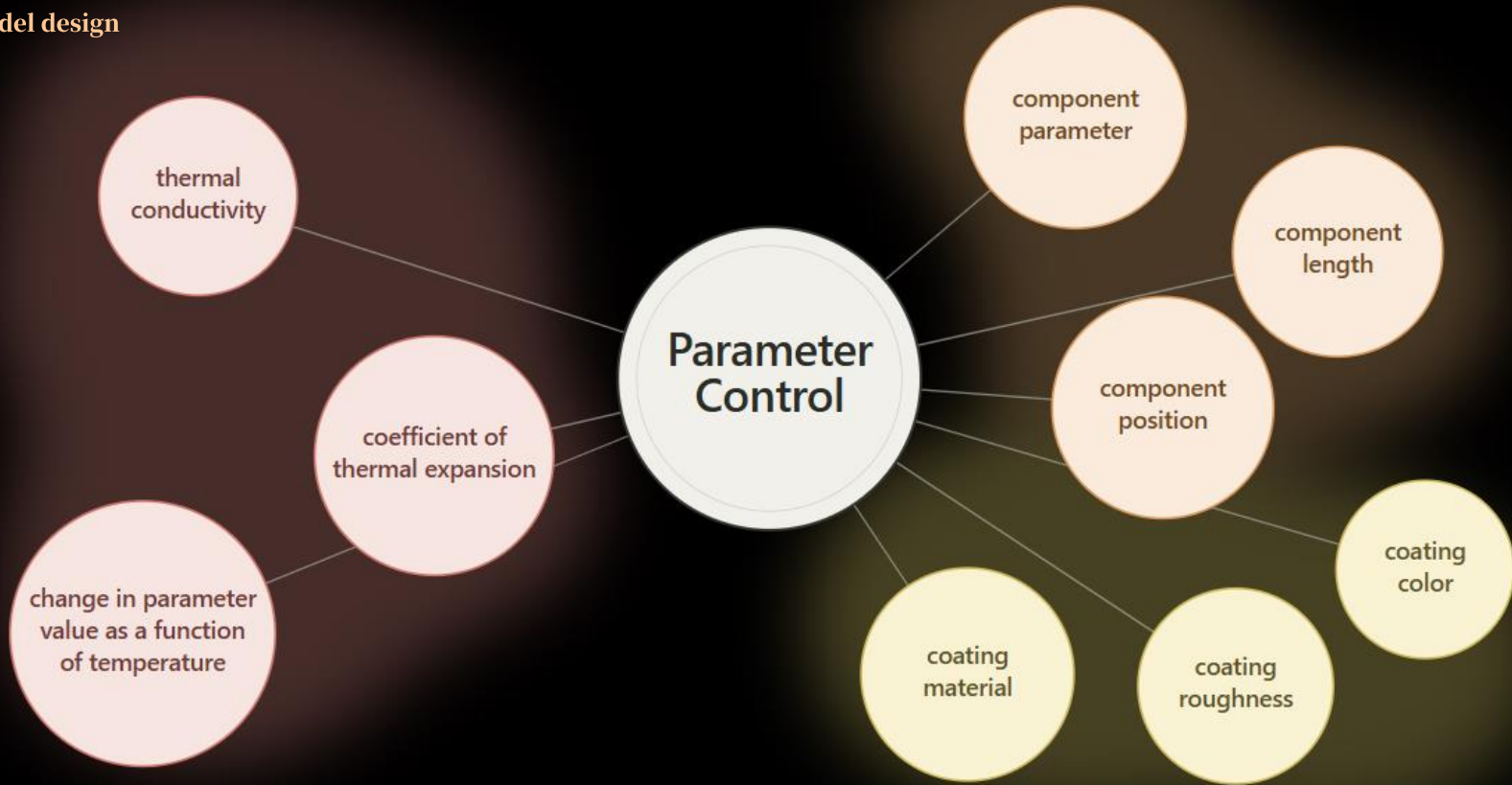
Fast

40+

Vast range

Procedure

Model design



● THERMAL

● COMPONENT

● SURFACE

Procedure

Stages to run computaion

Design & coding

- 1) Implement governing physical equations and environmental boundary conditions
- 2) Define material parameters

Run simulation

- 1) Apply boundary-value solver to obtain temperature field.
- 2) Compute local and integrated total thermal expansion.

Produce graphs

- 1) Produce parallel comparative plots across varied inputs.

Identify & fix / add

- 1) Review simulation outputs and identify limitations.
- 2) Adjust model to reflect real-world circumstances.

Results

FINANCING PLAN

01 Base Material

- Materials with higher thermal conductivity and low thermal expansion work better.
- Spacecraft structural strength must also be considered.

02 Length / frequency

- Insert material should match base-material properties to minimize boundary thermal resistance.
- Individual segments cannot be overly long / frequently placed.

03 Configuration

- Inserts placed near the heat-input hot end produce more prominent improvement on increasing uniformity.

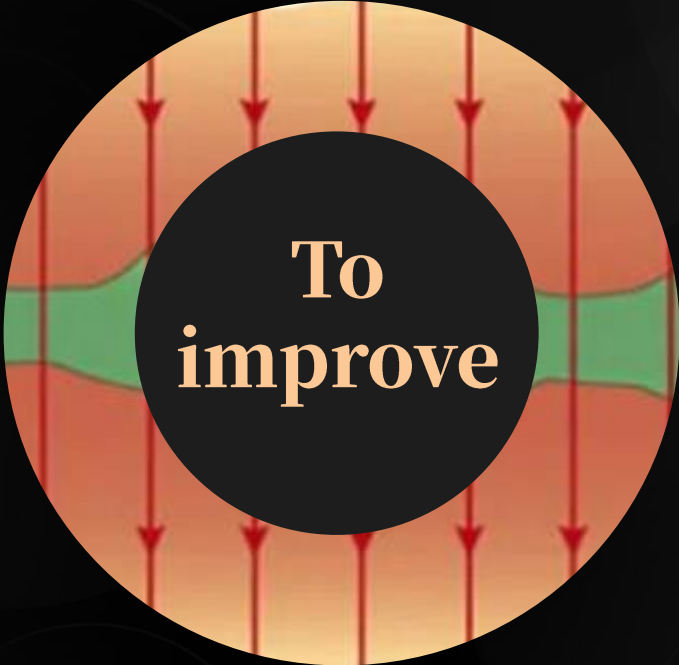
04 Coating

- Highly-reflective surface coatings are more effective.
- Should reduce the overall roughness of the surface while remaining a good aerodynamic performance.



Limitations

Simplification and further topics



**To
improve**

Function about temperature

Parameters including thermal conductivity and thermal-expansion coefficient are complicated functions of temperature.

Interfacial thermal contact resistance

Thermal contact resistance at boundaries between inserts and base metal is hard to define / modelize.

Computational limit

Intrinsic numerical calculation errors / insufficient precision due to limited computing power.

THANKS

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