



Design and Manufacturing Research for a Lean World Workshop

Analytical Models as Design Tools for Electronics Cooling Applications

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Outline

- Web-based and spreadsheet design tools based on analytical analyses
- Physically-based, minimal input, meaningful output
- Web tools: www.mhtlab.uwaterloo.ca/tools.html
- Spreadsheet tools: rix@mhtlab.uwaterloo.ca

Thermophysical Properties of Liquids & Gases



- Function of temperature
- Gases: air, argon, nitrogen, carbon dioxide
- Liquids: water, ethylene glycol, mixtures

The screenshot shows a web browser window titled "MHTL--Online Calculations - Microsoft Internet Explorer". The page content includes a navigation bar with "online tools" and a main section titled "Fluid Properties Calculator".

Input Values:

| | |
|--------------|---------------------|
| Fluid: | Ethylene Glycol 30% |
| Temperature: | 20 (degrees C) |
| Digits: | 5 |

Results:

| | | |
|----------------------|-----------|----------------------|
| Density: | 1.0376E+3 | (kg/m ³) |
| Dynamic Viscosity: | 2.1671E-3 | (kg/m.s) |
| Kinematic Viscosity: | 2.0885E-6 | (m ² /s) |
| Specific Heat: | 3.7141E+3 | (J/kg.K) |
| Conductivity: | 0.48418 | (W/m.K) |
| Prandtl number: | 16.623 | |
| Thermal Diffusivity: | 1.2564E-7 | (m ² /s) |

A "Calculate" button is located below the input fields.

Natural Convection Models for Heat Sinks

- Plate fin and radial fin configurations
- Solves for source temperature or heat flow rate

Model Specifications

Configuration:

Solve for:

Non-Uniform Fin Temperature:

Back Insulated:

Fin Material Conductivity k [$W/m^{\circ}C$]:

Maximum Outer Dimensions

[What is this?](#)

Depth $H + t_p$ [mm]:

Length L [mm]:

Width W [mm]:

Input Values and Results

Baseplate Thickness t_p [mm]:

Fin Length H [mm]:

Number of Fins:

Fin Spacing b [mm]:

Fin Thickness t [mm]:

Contact Conductance h_c [$W/m^2 \cdot ^{\circ}C$]:

Heat Flow Q [W]:

Ambient Temperature T_a [$^{\circ}C$]:

Diagram labels: t_p , H , h_c , T_s , Q , g , b , t

Effective Conductivity of Multilayered Substrates

- Effective conductivity calculator based on Fourier series analysis
- Up to 20 layers, pre-programmed material properties available
- Calculated k effective based on relative source size, position and edge conditions

Effective Conductivity (ID:9) - Microsoft Internet Explorer

Effective Conductivity of Multilayered Substrates

| Substrate | | |
|--------------------------------------|-----------|-----|
| Length (mm) | L | 100 |
| Width (mm) | W | 100 |
| Convective Coefficients (W/m^2K) | h_{top} | 5 |
| | h_{bot} | 5 |
| Number of Layers | | 3 |

| Layer # | Composition | Conductivity k (W/mK) | Thickness t (mm) | Edge Conductance h_{edge} (W/m^2K) |
|---------|-------------|-------------------------|--------------------|--|
| 1 | Other | 10 | 1 | 0 |
| 2 | Other | 10 | 1 | 0 |
| 3 | Other | 10 | 1 | 0 |

| Heat Source | | |
|-----------------------------------|-------|----|
| Length (mm) | L_s | 40 |
| Width (mm) | W_s | 40 |
| Position (mm) (lower-left corner) | X | 30 |
| | Y | 30 |
| Power (W) | Q | 3 |

Spreading Resistance Calculators



- Circular and rectangular substrates
 - ✓ Single and two layers
 - ✓ Finite, semi-infinite (flux tube) and infinite
- Circular, strip and rectangular sources
 - ✓ Isoflux
 - ✓ Parabolic
 - ✓ Equivalent Isothermal
- Edge cooling calculators are available

Spreading Resistance of Isoflux Rectangles and Strips on Compound Flux Channels - Microsoft Inter...

File Edit View Favorites Tools Help Links >>

Finite Compound Channel with Rectangular Heat Source

| Input Values | | |
|---------------------------------------|-------|----------------------------------|
| Thermal Conductivity (W/mK) | k_1 | <input type="text"/> |
| | k_2 | <input type="text"/> |
| Thickness (mm) | t_1 | <input type="text"/> |
| | t_2 | <input type="text"/> |
| Source Dimensions (mm) | $2a$ | <input type="text"/> |
| | $2b$ | <input type="text"/> |
| Flux Channel Dimensions (mm) | $2c$ | <input type="text"/> |
| | $2d$ | <input type="text"/> |
| Film Coefficient (W/m ² K) | h | <input type="text"/> |
| Number of Terms | | <input type="text" value="500"/> |

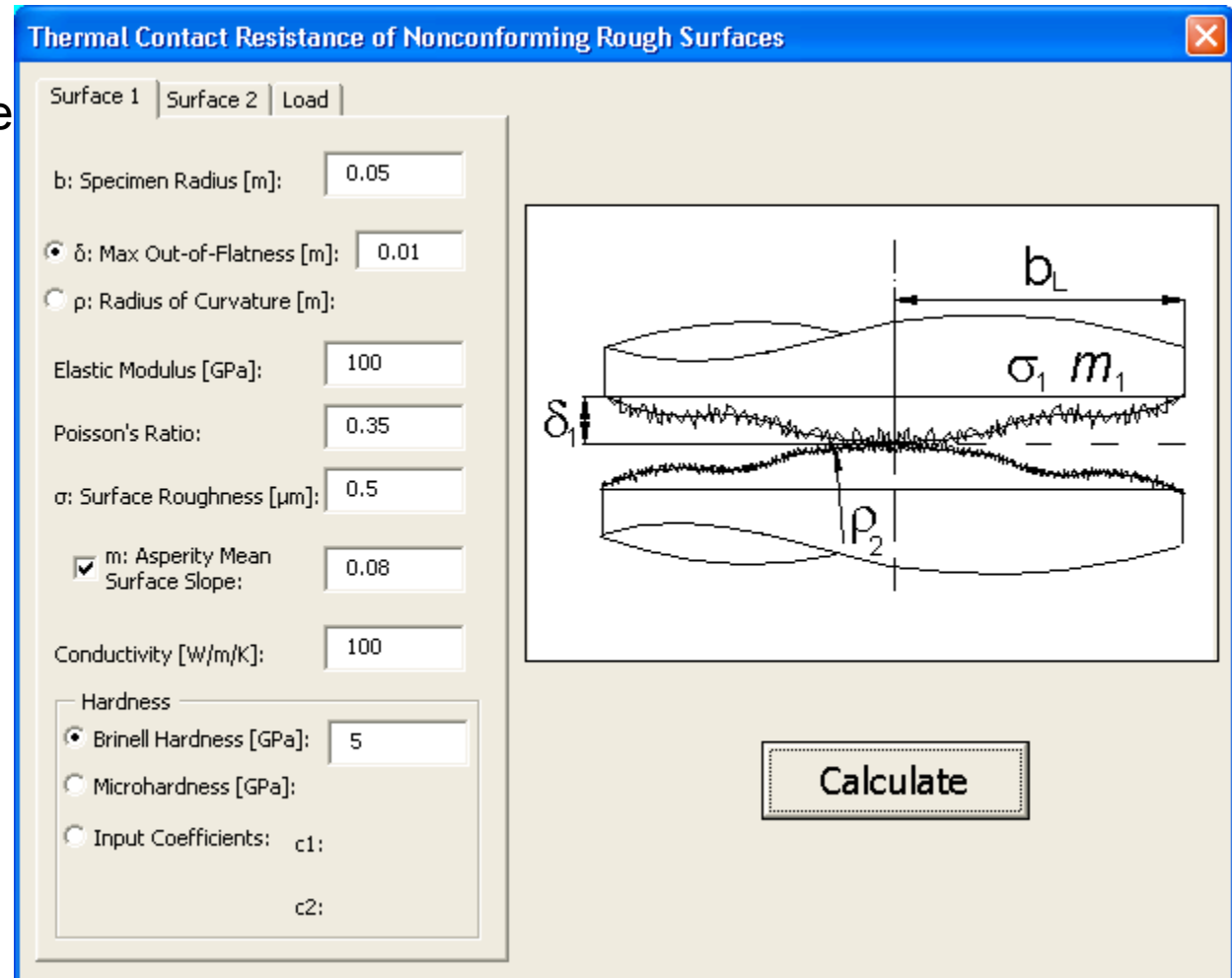
Number of Digits

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Thermal Contact Resistance for Non-conforming Rough Surfaces



- Excel - VBA implementation of analytical model
- Calculation based on readily available surface parameters, such as
 - ✓ surface slope
 - ✓ hardness
 - ✓ out-of-flatness



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