LESSON 1

Transient Thermal Analysis of a Heating Element

Objectives:

• Create a solid model of the heating element.

• Apply thermal load of convection, heat generation, heat flux, and fixed temperature to the model.

• Run a transient heat transfer analysis of the plate.
Model Description:

A rectangular heating element is subjected to a heat flux along one of its long edges. The opposite edge is cooled by convection, and a temperature controlled fitting holds the bottom of the element at 50 degrees Celsius. It can be assumed that, despite the heat generation processes/materials within, the heating element's thermal properties are identical to those of aluminum. The aim of this exercise is to determine the transient thermal response of the heating element for a period of 1000 seconds from a ‘cold start’ (i.e. the unloaded condition).

Below is shown an aluminum plate which is subjected to several types of thermal loading. You will create this model, and analyze it to determine the transient behavior of the temperature for a period of 2 seconds.

Aluminum Plate
- $k = 204 \text{ W/m} \cdot \text{o C}$
- $C_p = 896 \text{ J/kg} \cdot \text{o C}$
- $\rho = 2707 \text{ kg/m}^3$

$q = q_{\text{vol}}(t) \text{ W/m}^3$
$q = q_{\text{flux}}(t) \text{ W/m}^2$

Thickness = 0.1 m
$T_0 = 50 \text{ o C}$
$T = 50 \text{ o C}$
$T_{\text{amb}} = 20.0 \text{ o C}$
$h = 10.0 \text{ W/m}^2 \cdot \text{o C}$
Exercise Procedure:

1. Start up MSC/NASTRAN for Windows 3.0.2 and begin to create a new model.

   Double click on the icon labeled MSC/NASTRAN for Windows V3.0.2.

   On the Open Model File form, select New Model.

   Open Model File: ____________________________

   New Model

2. Create the NASTRAN geometry for the plate.

   Geometry/Surface/Plane...

   Fill in the table as the following:

<table>
<thead>
<tr>
<th></th>
<th>X:</th>
<th>Y:</th>
<th>Z:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base:</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Point 1:</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Point 2:</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

3. The following table will appear on your screen. Fill in the appropriate dimensions.

   Width (along Plane X): ____________

   Height (along Plane Y): ____________

4. To fit the display onto the screen, use the Autoscale feature.

   View/Autoscale... < CTRL A >
5. Set the default size for the mesh.

**Mesh/Mesh Control/Default Size...**

- **Size:** 0.1
- **OK**

6. Create a material called **alum**.

   From the pulldown menu, select **Model/Material**.

**Model/Material...**

- **Title:** alum
- **Mass Density:** 2707
- **Conductivity, k:** 204
- **Specific Heat, C_p:** 896
- **OK**
- **Cancel**

7. Create a property called **plate** to apply to the members of the plate itself.

   From the pulldown menu, select **Create/Property**.

**Model/Property...**

- **Title:** plate
- **Material:** 1..alum
- **Thickness, T_{avg} or T_1:** 0.1
- **OK**
8. Create a property called **solid**, to be applied to the model later.

```
Title: solid
Material: 1..alum

Elem/Property Type...

Volume Elements: 1 Solid

Mesh/Geometry/Surface...

Select All
OK

Property: 1..plate

OK
```

9. Create the mesh for the model.
Your model should appear to be like the following:

Figure 1: Plate model with meshed surfaces

10. Remove the labels from the screen.

View/Options...  
< CTRL Q >

Quick Options...

Labels Off

Done

OK
11. Extrude the 2D shell elements into 3D solid elements.

**Mesh/Extrude/Element...**

- Select All
- OK

*Property:*

- 2..solid

*Elements Along Length:*

- 1

- [Delete Original Elements]

- OK

**X:** | **Y:** | **Z:**
---|---|---
Base: | 0 | 0 | 0
Tip: | 0 | 0 | 0.1

- OK

When asked “OK to Delete 300 Select Element(s)?”, respond **Yes.**

**Yes**

12. Create a uniform temperature loading for the model.

First, a load set must first be created before creating the appropriate model loading.

**Model/Load/Set...**

*Title:*

- transient

- OK

Next, apply a uniform default temperature to the model.

**Model/Load/Body...**

*Active*

- Default Temperature: 50

- OK
13. Create time-dependent functions for the heat flux and volumetric heating.

Model/Create/Function...

Title: flux_time
Type: 1.. vs Time

X:  Y:
0   1
10  1.25
30  1.75
50  2
100 2

OK

Title: qvol_time
Type: 1.. vs Time

X:  Y:
0   10000
10  12000
30  13000
50  14000
100 14000

OK

Cancel
14. Apply a fixed temperature of 50 degrees to the bottom edge of the model.

**Model/Load/Nodal...**

Hold down the shift key and drag a box around the bottom edge nodes. (you might need to move the entity select menu)

![OK](image)

*Type: Temperature*

*Temperature: 50*

15. Create the heat flux for the model.

**Model/Load(Elemental)...**

Hold shift and drag a box around the right edge of the model.

![OK](image)

*Type: Heat Flux*

*Value: 5000*

*Function Dependence: 1..flux_time*

16. Create the free convection for the model.

Hold shift and drag a box around the left edge of the model.

![OK](image)

*Type: Convection*

*Coefficient: 10*

*Temperature: 20*
17. Create the volumetric heat generation for the model.

Hold shift and drag a box to select the four left columns of elements in the model.

**Type:** Heat Generation

**Value:** 1

**Function Dependence:** qvol_time
18. Create the input file and run the analysis.

**File/Analyze**

*Analysis Type:* 21..Transient Heat Transfer

*Number of Time Steps:* 100

*Initial Time Increment:* 10
19. When asked if you wish to save the model, respond Yes.

Yes

File Name: trans

Save

When the MSC/NASTRAN manager is through running, MSC/NASTRAN will be restored on your screen, and the Message Review form will appear. To read the messages, you could select Show Details. Since the analysis ran smoothly, we will not bother with the details this time.

Continue

20. Remove the thermal loading markers from the screen.

21. Create a final temperature distribution contour plot.

Model Style: Quick Hidden Line

Contour Style: Contour
22. Redfine the spectrum and ranges used to plot the temperature contours.

View/Options... (or use <F6>)
PostProcessing: PostProcessing
Options: Contour/Criteria Levels
Level Mode: Max Min
Minimum: 50.0
Maximum: 57.0
Apply
OK

Notice the effects of the free convection, heat flux, fixed temperature, and heat generation on the temperature distribution. Compare your results against those depicted in Figure 3.

23. Create an XY plot of the temperature along the left edge as a function of Y.

First, you will need to create a group for the elements in the XY plot.

Group/Set...
Title: temp along the left edge
OK

Group/Node/Id...
ID: 342
to: 672
by: 21
Figure 3: Transient Thermal Analysis
24. Now, create the XY plot.

View/Select... (or use <F5>)

XY Style: XY vs Position

XY Data...

Position: Y

Group: Select

1..temp along the left edge

Output Set: 5..Case 9 Time 190

Output Vector: 31..Temperature

OK

OK

Compare your results with Figure 4.

When done, exit MSC/NASTRAN for Windows.

File/Exit
This concludes this exercise.

Figure 4: Temperature along the left edge vs Vertical position