Bake & Grill

ME4041 Computer Graphics and CAD

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I. Introduction

The Bake & Grill is a household appliance designed to transform the cooking experience. In today's fast paced society, many individuals prepare food only for themselves and dine alone while trying to squeeze meals in their busy schedule. Currently, there is no device on the market that addresses the needs of these individuals. Students, businessmen, vacationers, and many others need to have a portable solution to preparing food in a quick and effective fashion. The Bake & Grill will fill this need by functioning as both a high efficiency convection oven and a nonstick dual-sided griddle that is collapsible and portable.

By combining the griddle and oven into one package, the Bake & Grill allows users to have a full kitchen experience although they may not have the space for an entire kitchen set. The Bake & Grill was designed to improve the cooking experience by reducing cooking time while using minimal counter space. This product will be able to prepare a meal in the oven as well as on the griddle simultaneously. The device includes a storage feature, where the Bake & Grill will collapse on itself providing easy storage and portability. The convection baking system includes a crumb collector, while the non-stick griddle with grease collector makes for a fast cooking time with minimal cleaning required. The compact cooking solution is perfect for dorms, hotel rooms, RV's, apartments, and other small living areas.

This report details the device's design and investigates the products functionality. Moreover, this report defines how and why the Bake & Grill is a viable solution for compact cooking.

II. Objective

The objective of the Bake & Grill is to address the need of preparing food in compact environments by creating an efficient and portable solution that retains the cooking experience of a full kitchen. The device will provide both baking and grilling capabilities and come in a form that is sleek and visually appealing while functioning efficiently and safely.

III. Modeling

The Bake & Grill was developed using Siemens NX 8.0 to create a CAD model that replicates the physical device. In order to model the Bake & Grill, a solid body representing the industrial design of the product was created first. The solid body was then cut apart and shelled out into several exterior components. Features were developed on these exterior components that would mate with interior components, and finally the interior components were developed. The following sections describe the modeling techniques used to create the exterior surfaces, exterior components, and interior components.

III. A. External Surfaces

While the Bake & Grill's main function is to provide a portable and effective means for individuals to prepare food, it also provides a sleek and stylish design that appeals to appliance consumers. In developing the Bake & Grill, the aim was to create an exterior surface that seamlessly blended the oven and griddle and provide the consumer with an appearance of one complete product rather than two products connected together and placed in the same package. Complex surfaces were used to create this seamless transition.

First, a skeleton of curves was designed that acted as a wireframe which the device would fit within. The main curves that compose the skeleton are the spine of the griddle, the spines of the side walls, the guideline of the oven door, and the curve of the front face. These splines were created using the Studio Spline command in NX. Figures 1-4 show the creation of the wireframe.

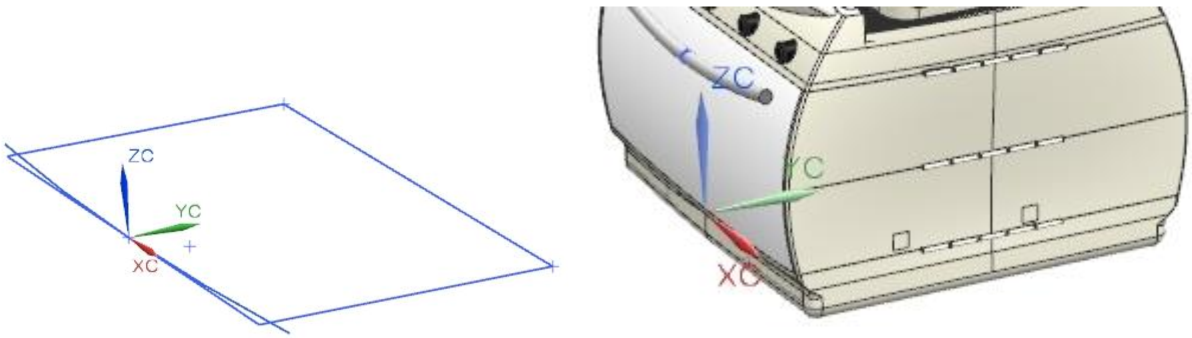


Figure 1. Sketch of Oven Base

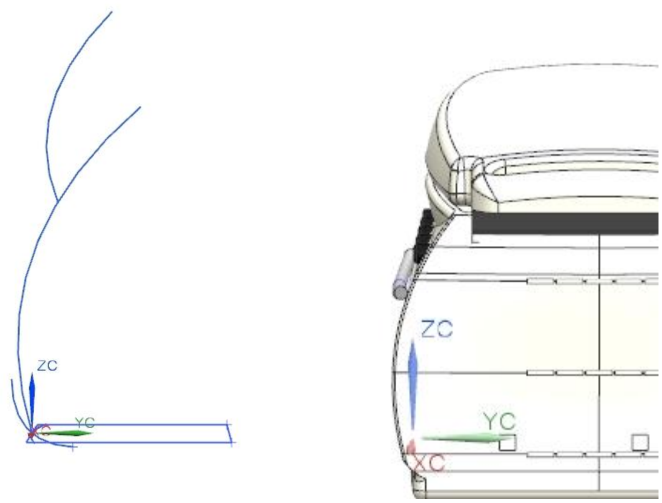


Figure 2. Oven Door and Griddle Edge Splines

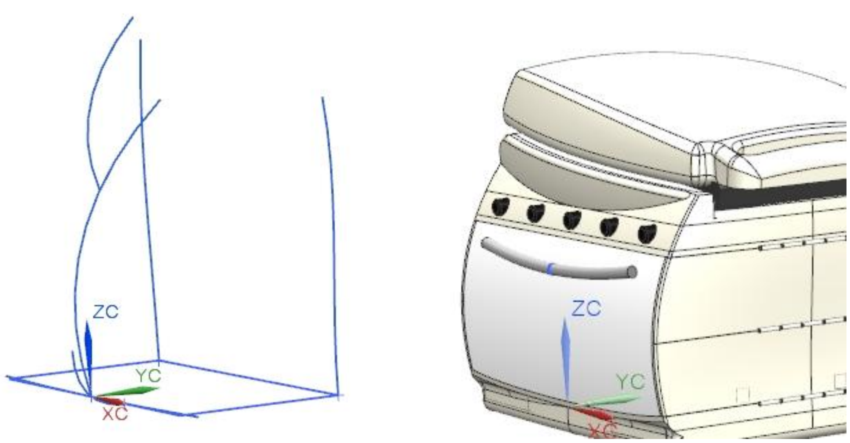


Figure 3. Side Wall Splines

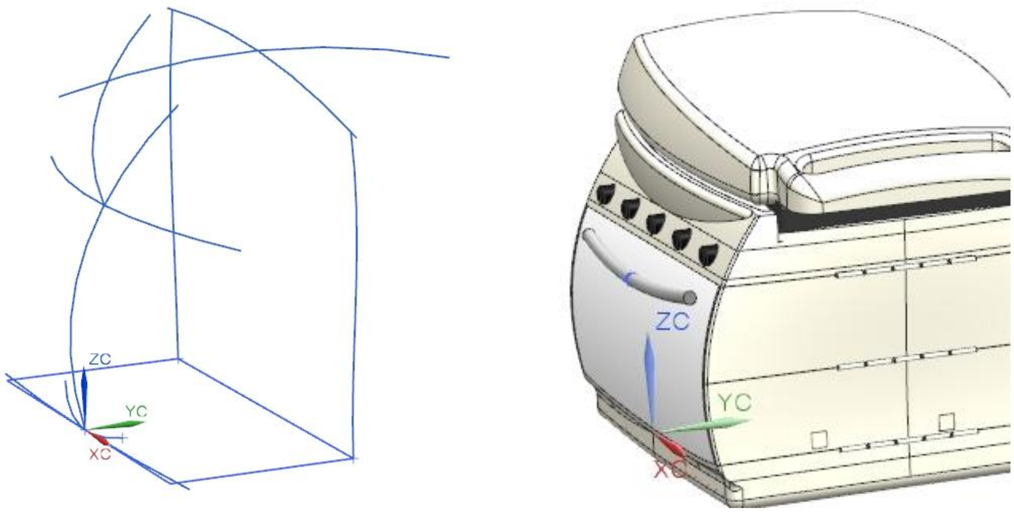


Figure 4. Bake & Grill Wireframe

After the wireframe of the device was created, surfaces were made to represent the boundaries of the solid. The command “Swept Surface” was utilized to create a surface using one curve as a spine and another curve or edge as a guideline. First, the base of the oven was created from the sketch shown in Figure 1 using the “Swept” function. Similarly, the front walls of the oven and griddle were created using the splines shown in Figure 2 and sweeping them along the guidelines shown in Figure 4. Next, the top of the griddle was created using the griddle spine and guidelines from Figure 4. The front and top surfaces are shown in Figure 5.

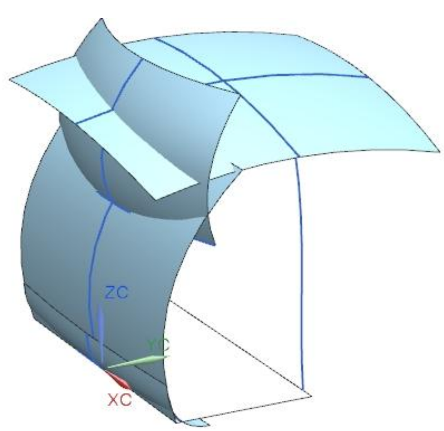


Figure 5. Front and Top Surfaces of Bake &Grill

Note that the surfaces in Figure 5 represent only half of the exterior surfaces. The shown surfaces were mirrored to complete the exterior surfaces because the Bake & Grill is symmetric across the center plane of the griddle.

After the surfaces for the front and top of the device were created, the surfaces were trimmed to the boundaries of the device. Then, the side walls were created using the “Through Curve Mesh” command. Finally, the surfaces were mirrored across the center plane of the griddle and sewn together to form a solid as shown in Figure 6.

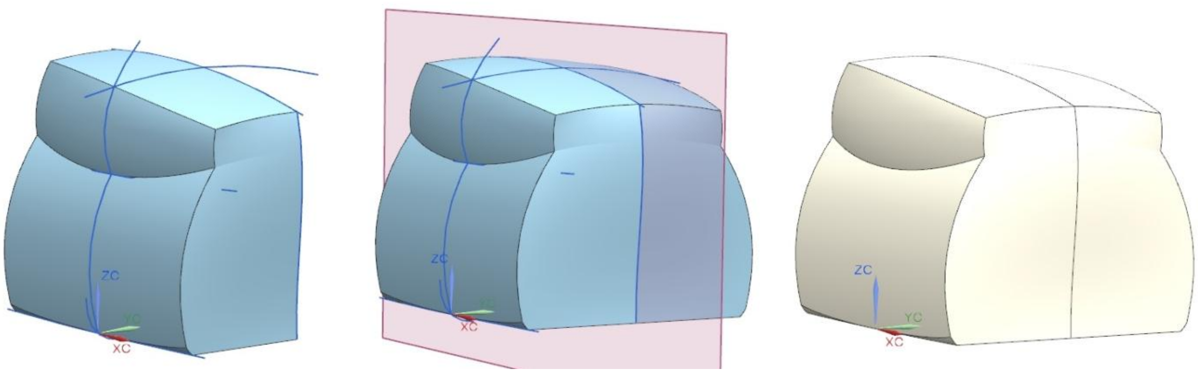


Figure 6. Mirroring and Solid Formation of Exterior Surfaces

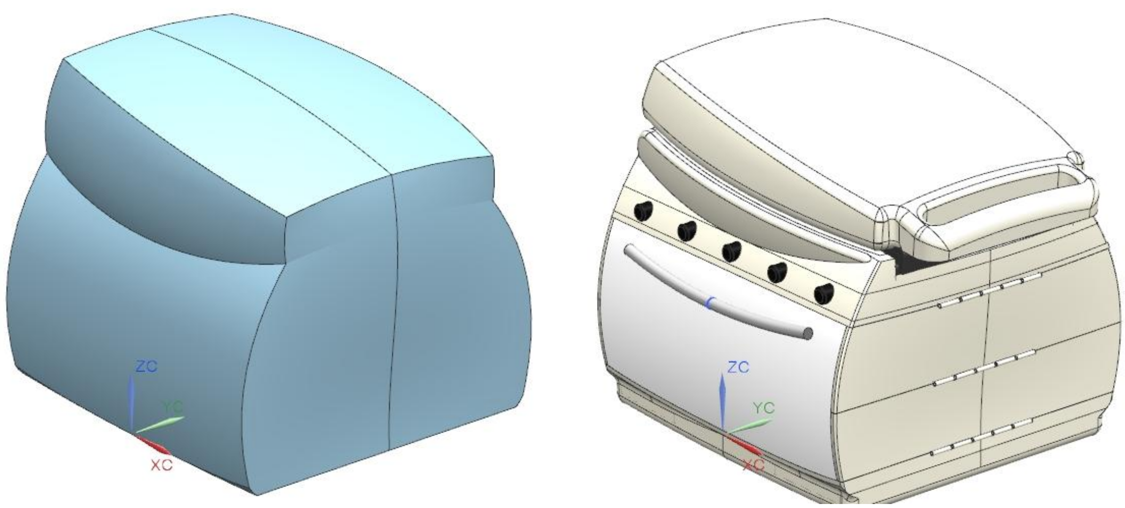


Figure 7. Bake & Grill Solid Body

The final dimensions of the Bake & Grill are 16” wide by 14.5” deep by 15.5” tall. This size is comparable to modern toaster ovens; however, the height is slightly larger because of the griddle on the device.

III.B. External Components

After the Solid Body for the device was created, the body was split into exterior components. The main components split off of the body were the oven, oven door, griddle top, griddle bottom, user interface/control panel, and the side walls. Using the command “Split Body”, target bodies were divided by surface tools. Figure 8 shows the solid body being split into the oven, user interface/control panel, and griddle components by datum planes.

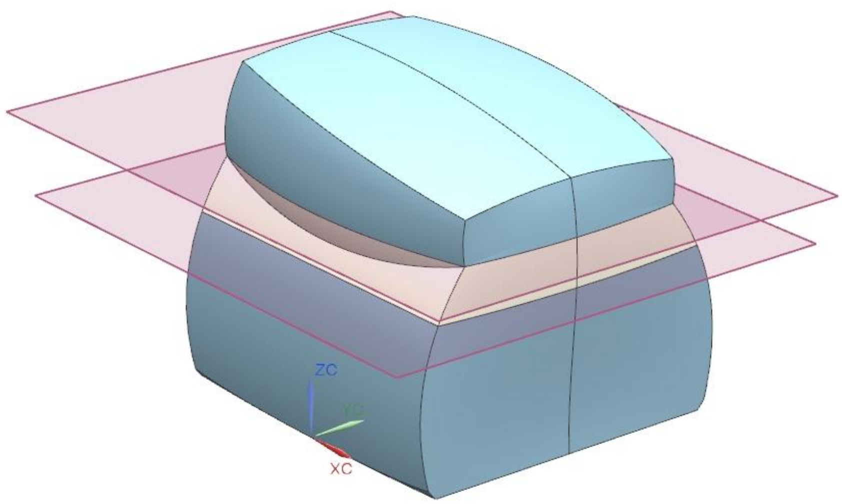


Figure 8. Griddle, Oven, and User Interface Split Bodies

Next, the oven was shelled out the external components of the subassembly were created using the “Split Bodies” feature. Figure 9 shows the creation of the oven door, which was made using a surface that represented the boundary of the door to split the solid body of the oven.

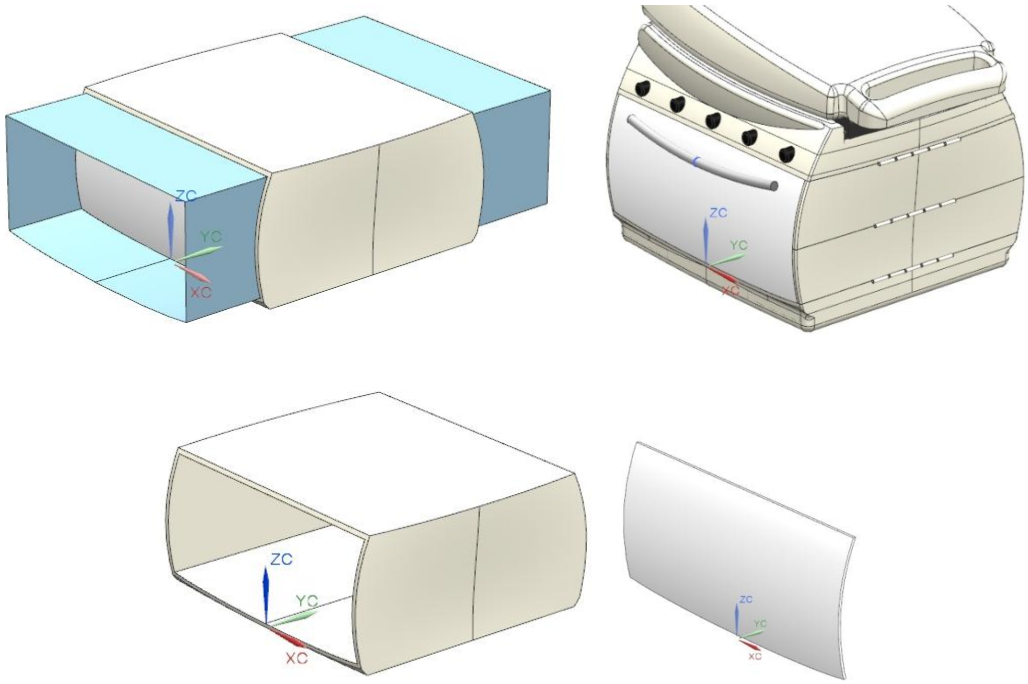


Figure 9. Oven Door and Exterior Creation

Additionally, the collapsible walls of the oven were split from the main body as shown in Figure 10.

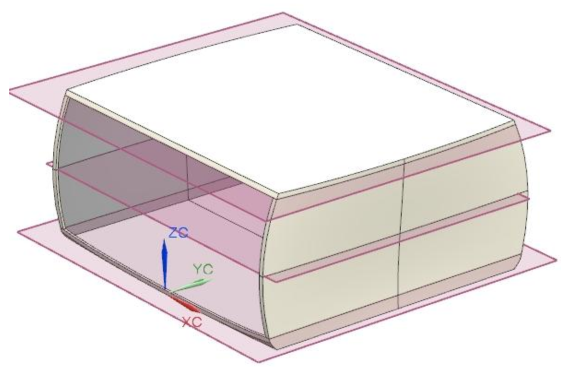


Figure 10. Collapsible Walls of the Oven

To connect these walls, hinges were created by extruding a cylinder with a flat along the seam between the walls. This feature was then patterned along the seam and mirrored across the center plane of the oven to create the hinges on the other half of the side walls. Finally, the cylinders were combined with the appropriate solid body to form the hinge.

Next, tracks were created on the interior of the lower walls to allow the cooking tray and crumb plate to be held securely while cooking. The tracks were extruded and patterned similar to the hinges. Figure 11 shows one of the bottom wall panels.

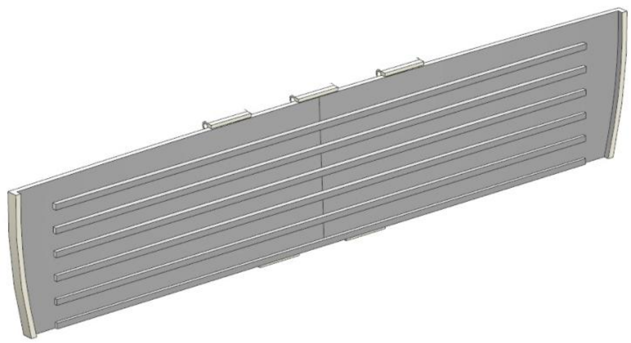


Figure 11. Side Wall Panel With Hinges and Tracks

Next, the base of the oven was expanded to provide a storage compartment and track and hinge system for the front oven door and back oven wall. The base of the oven was moved down 1.5" inches using the "Face Move" command. Next, a track on the sides of the oven base was created. This track acts a hinge when the oven in open and a track when the oven is being opened or closed. Figure 12 shows the expanded oven base and the track and hinge system for the front oven door.

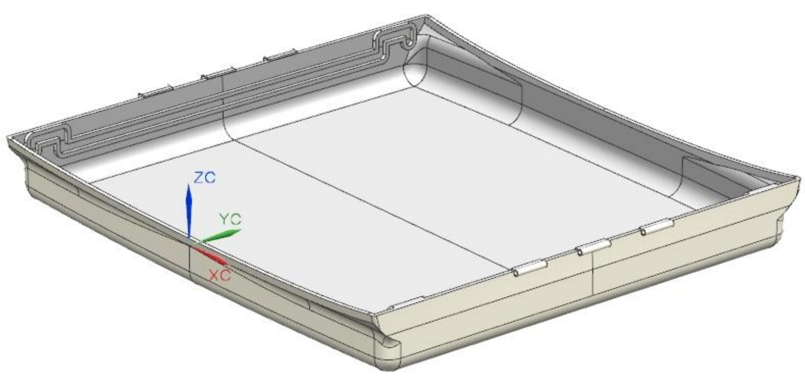


Figure 12. Oven Base

Additionally, the features on the oven door were created. One critical feature on the door is the interface with the hinge and track system on the base of the oven. This was created by extruding an angle from the oven door, then extruding a circular protrusion off of the angle. In addition to the track and hinge system, a handle was modeled onto the oven door for the user. The handle was formed by sweeping a circle across a spline that hugged the face of the oven door. Figure 13 shows the model of the oven door.

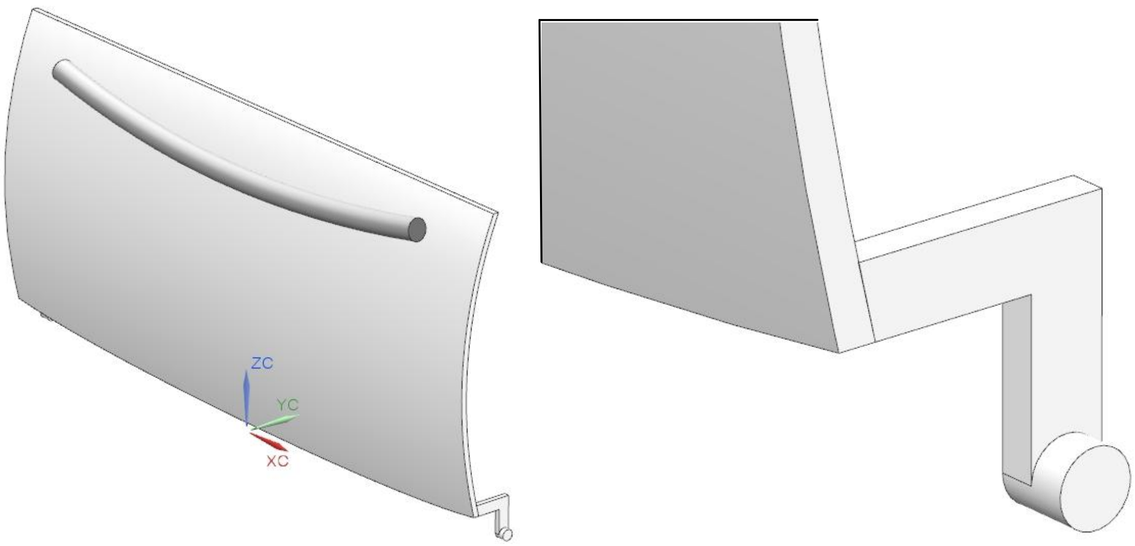


Figure 13. Oven Door

The rear wall of the oven was modeled identical to the oven door with the only difference being that there is no handle on the rear wall. Figure 14 shows the oven subassembly.

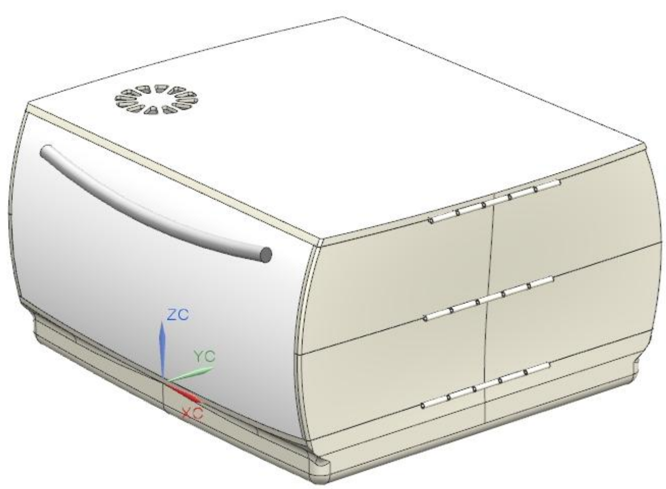


Figure 14. Oven Subassembly

The griddle components were then created by splitting the griddle solid body into the top and bottom griddle bodies using an angled datum plane. The plane was angled at 5 degrees which was chosen to allow the grease to flow into a trap while the food remained in place on the cooking surface. Figure 15 shows the creation of the top and bottom bodies of the griddle.

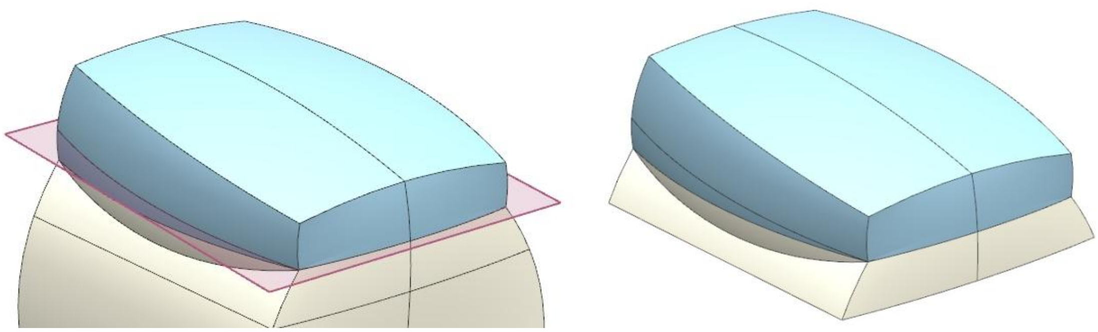
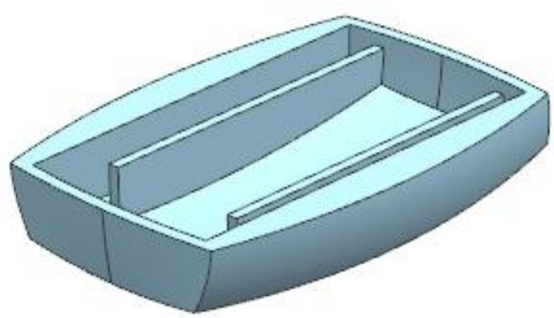


Figure 15 Top and Bottom Griddle Body Formation

For both the top and bottom griddle housings, the parts were shelled out with a wall thickness of 0.5" and internal ribs that interface with the cooking surfaces were created by extruding sketches up to the surface of the housing. The interior features of the top griddle housing are shown in figure 16.



Figurer 16. Interior Features of Top Griddle Housing

In addition to the internal features of the griddle, a handle for the user was created and blended into the exterior surfaces of the housing. The handle was created by first extruding a sketch of a cross section of the handle as shown in Figure 17. Next, the top face of the extrusion was replaced with the top surface of the griddle housing using the “Replace Face” command as shown in Figure 18. Then, the excess material on the handle was trimmed using the “Trim Body” command, and the final body of the handle was connected to the top griddle housing as shown in Figure 19.

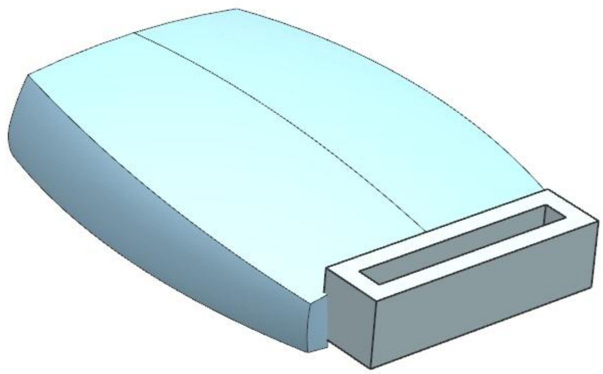


Figure 17. Handle Extrusion

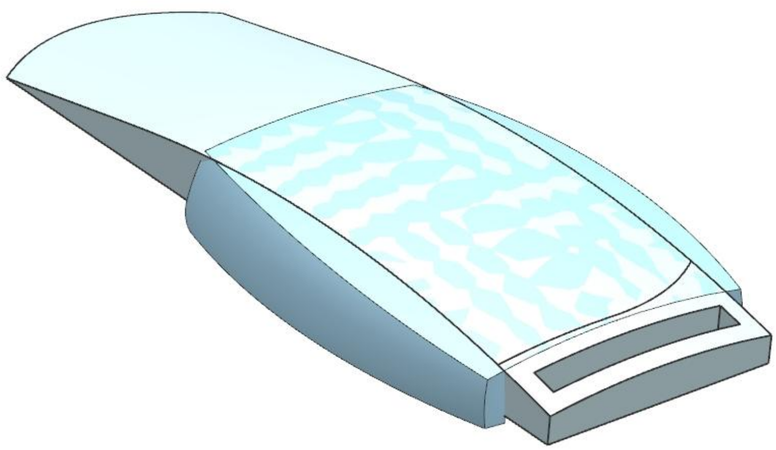


Figure 18. Face Replacement of Handle

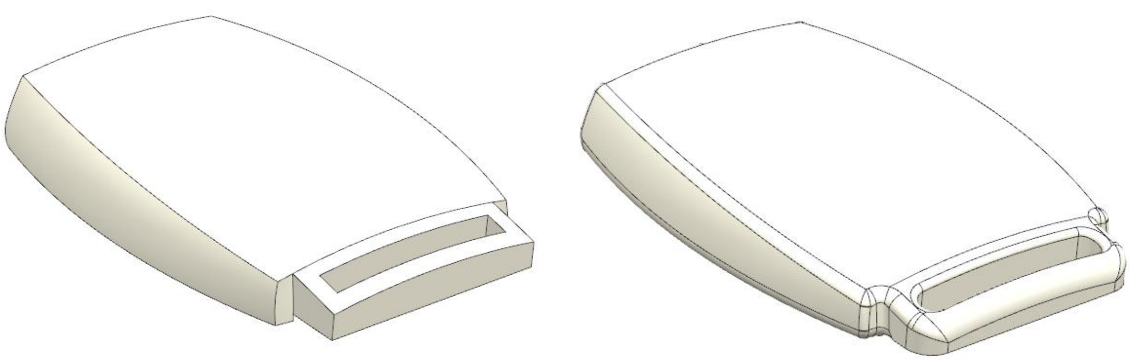


Figure 19. Trimmed Body and Union of Handle with Top Griddle Housing

After the handle was created, a recess on the underside of the housing was created for the hinge using the “Extrude”. Sharp edges were then blended and the component was complete.

Similar to the top griddle housing, the bottom griddle housing was shelled out and ribs were extruded to support the bottom cooking surface. After blending sharp edges, the bottom griddle housing was completed and is shown in Figure 20.

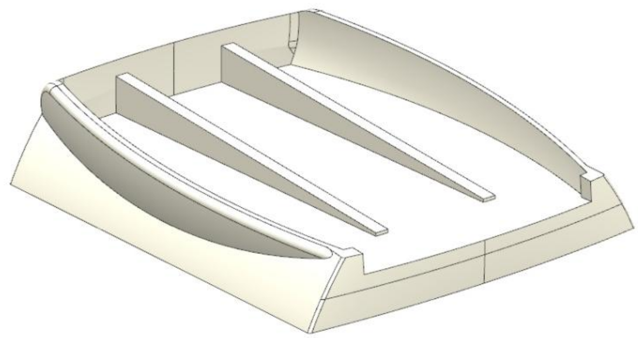


Figure 20. Model of Griddle Bottom Housing

Finally, the user interface/control system was modeled. The user interface includes knobs that control temperature, cook settings, and time for both the griddle and the oven. The control system will be made of preassembled electrical components, therefore the interior of the control panel was not modeled. Prior to the final assembly, all sharp edges on the exterior components were blended to create a seamless finish. Figure 21 shows the final assembly of the exterior components.

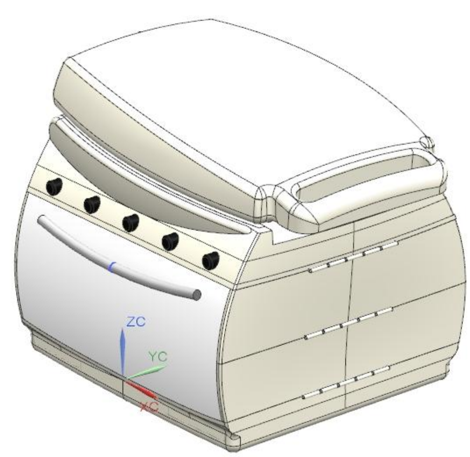


Figure 21. Exterior Components Assembly

III.C. Internal Components

The griddle components of the Bake & Grill were created to provide a large cooking area that effectively collected grease from the food to create a healthier dining experience. The first part created was the bottom griddle.

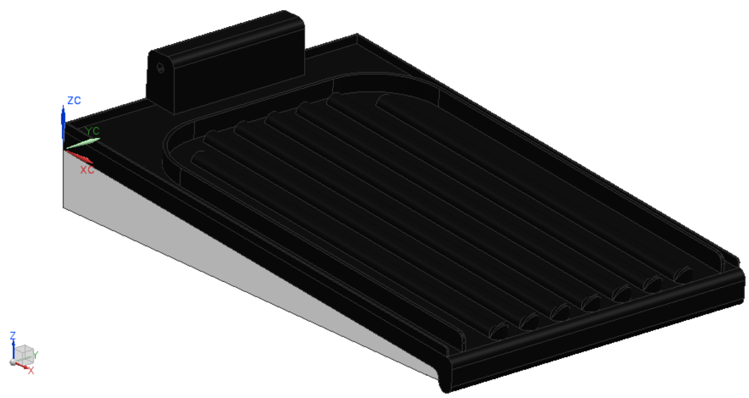


Figure 22. Bottom Griddle

The dimension of the component is 9 inches by 15 inches, and it was modeled such that the bottom grilling surface matches up with the cooking surface of the top griddle to optimize grilling space. The grilling surface which is steel coated with a nonstick material such as Teflon is created by the side profile. The surface was created at a 5° angle so that the grease can easily slide down the grill and into the grease trap.

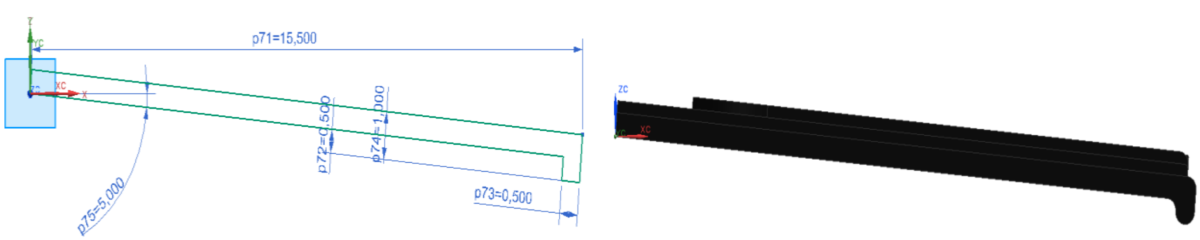


Figure 23. Side View of 5° Slope

Once the overall surface was created, the elevated grilling surfaces were created. A datum plane was created 0.5" above the surface and square shapes were extruded downwards to the surface.

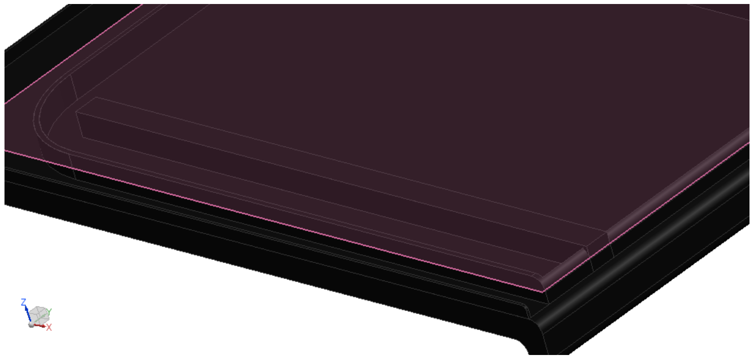


Figure 24. Heating Element Creations

A second datum was created on the side profile of the newly extruded part so that the angle can be cut into the surface to create the triangle wedge like shape at the end of the grill. Once the overall shape was created, the element was then rounded off with the fillet command till the overall desired shape was created.

Figure 25. Rounding Element Creation

Then datums were created at an offset of 0.25” apart and then the features were mirrored across the entire surface.

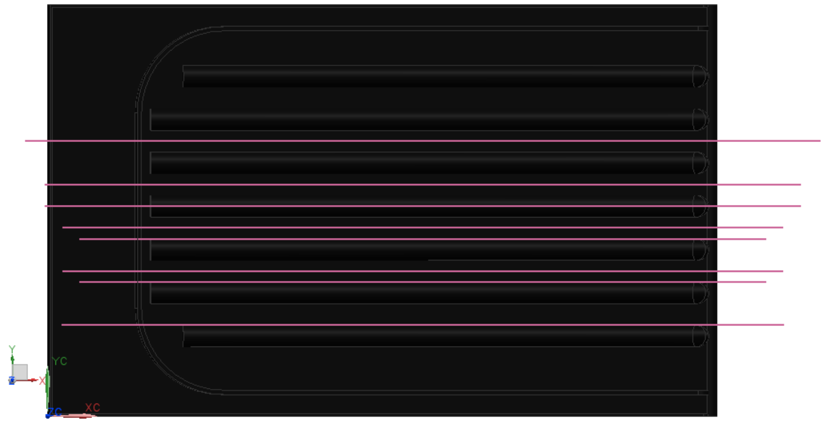


Figure 26. Mirroring Elements

The next component created was the housing of the bottom grilling surface. The plastic component was made by following the contour of the grilling surface to create a seamless transition from the grilling surface.

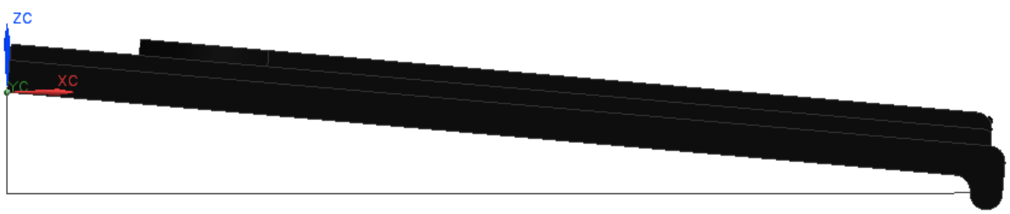


Figure 27. Bottom Grilling Housing

The next feature created was the hinge that connects the top and bottom surfaces together of the grill. The hinge was created by placing a datum in the middle of the bottom grill and extruding both directions to the desired length.

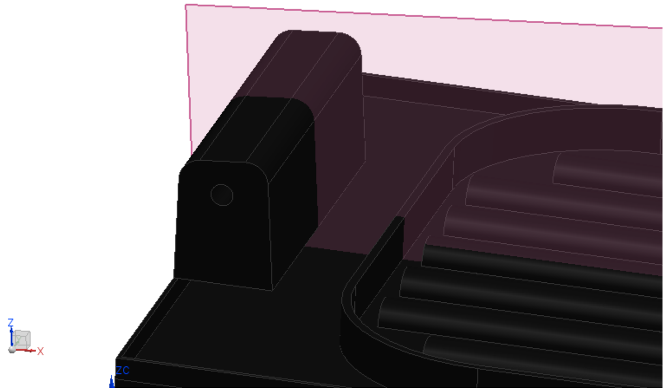


Figure 28. Hinge

The next component created was the top half of the grilling surface. To make sure the two halves would close on top of each other, the widths of the bottom and tops had to be offset by 0.5”. The top halve was created similarly to the bottom half. The grilling elements were also created the same way as the bottom halve, however the height of the top halve is smaller than the bottom half.

Figure 29. Top Grill’s Elements

The top grilling surface also does not have the wedge feature that the bottom grilling section to keep the food from sliding off the grill in the open position. Similar to the bottom section, the plastic housing was created by a 3 point curve off the grilling surface and extruded to a desired height.

The oven consists of many internal parts, which provide the heating mechanism for the oven as well as the cooking surface. The heating elements were created by extruding a circle with a diameter of

0.25 inch to 15.5 inches. A thin hole was cut with a diameter of 0.23 to create the outer casing of the heating element. This part can be seen in Figure 30

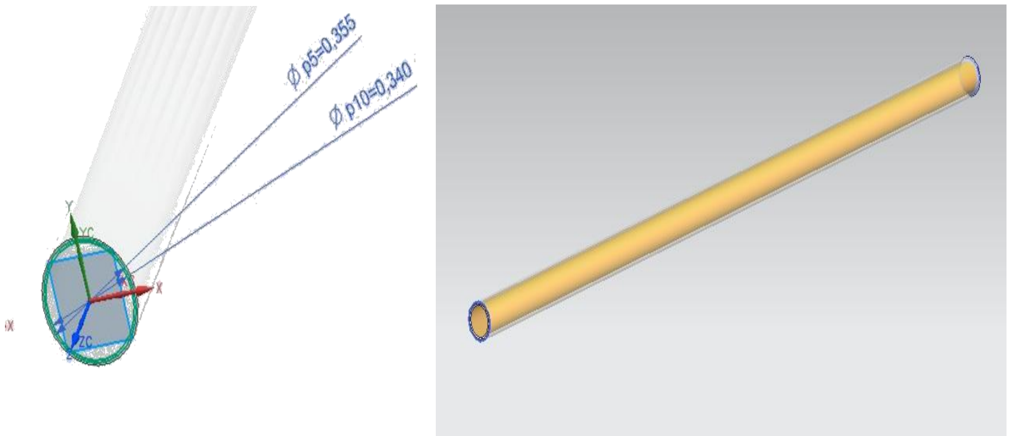


Figure 30 Heating element

This heating element has a center made of a Nichrome wire with insulation surrounding it to prevent damage to the wire.

The holder for the heat element was created by creating a square with sides of 0.6 inch and thickness of 0.4 inch. A circular hole was then subtracted from the square with a diameter of 0.25 inch and 0.3 inch deep. This heat element holder can be seen in Figure 31

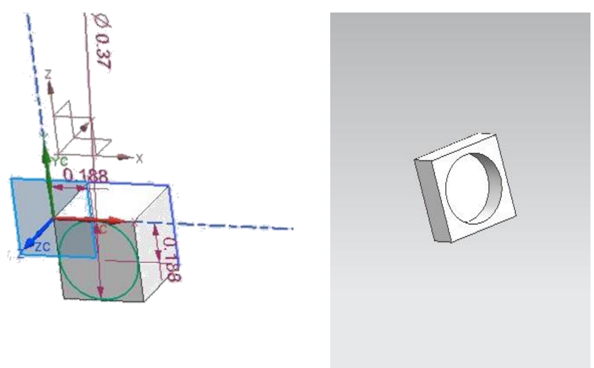


Figure 31 Heat element holder

The wires from the heating elements will run through the holder to the user interface.

The heating elements are then protected by a cover, since food particles often fall off of the tray. This part was constructed by creating the shape of the cover. The thickness of the cover is 0.25 inch and has a length of 16 inches. Small holes of diameter 0.15 inch were pattern on the cover to resemble existing covers. This part can be seen in Figure 32

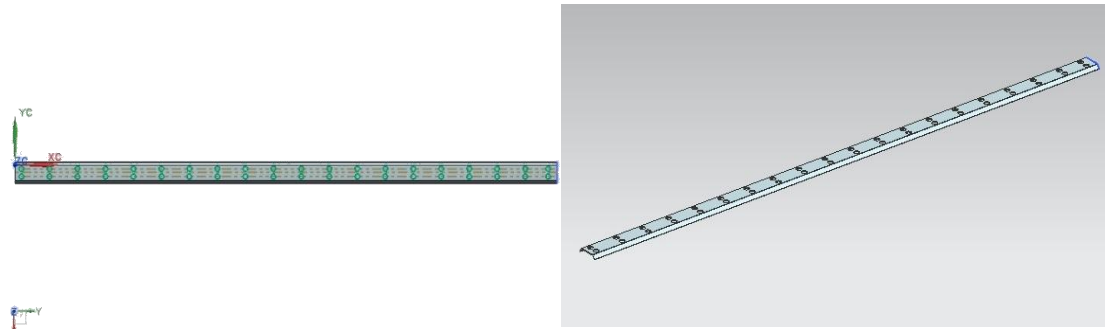


Figure 32 Heating element cover

The racks that hold the tray was then constructed. This was done by creating a frame in sketch mode. Once the frame was done, the tubing command was used to creating the racks. The diameter used to creating the racks was 0.25 inch. This part is shown in Figure 33

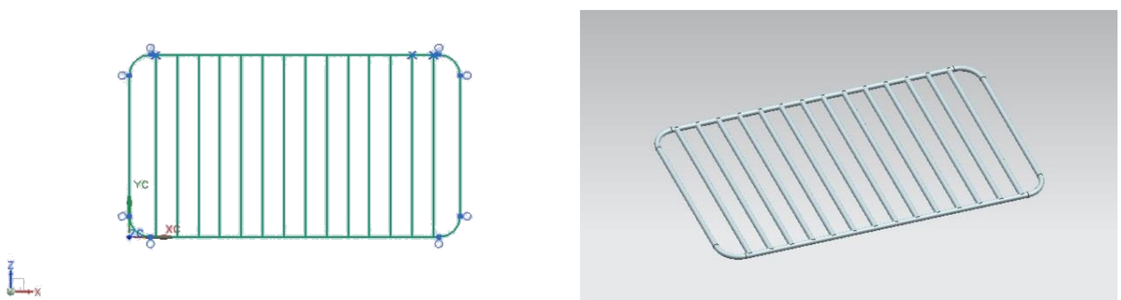


Figure 33 Racks for oven

The final internal part for the oven was the tray. The tray was made by creating a thin sheet and sides with thickness 0.2 inch. The sides are filleted with a radius of 0.2 inch. Once the part was extruded to 14 inches, the final two sides had to be created. By using the mirror command, both sides were identical. The sides were then edge blended to give a more precise look to the tray. The tray is shown in Figure 34

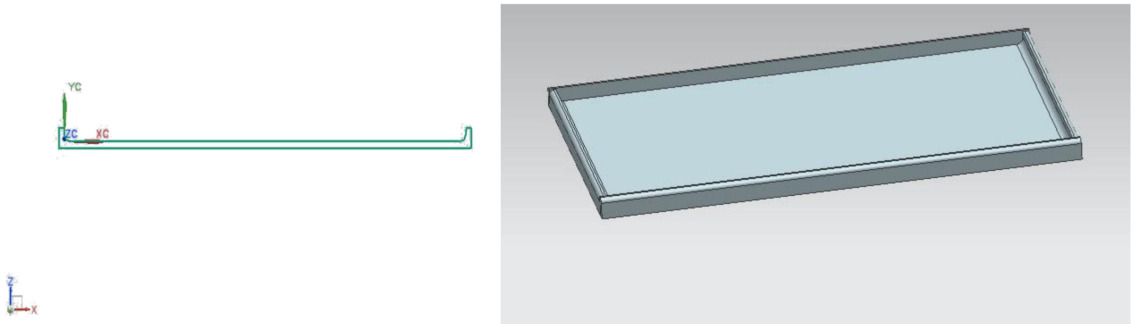


Figure 34 Tray

The components were then assembled using various mating conditions, and the final assembly was configured for 3 different cases: griddle open, expanded oven, and collapsible oven. The figures 35-37 represent the assembly configurations.

Figure 35. Expanded Configuration

Figure 36. Collapsed Configuration

Figure 37. Open Configuration

IV. Analysis

When designing the Bake & Grill, it was critically important to consider how features of the device would react in certain environments. It was also important to consider which materials were most effective for the system. Using finite element analysis, critical features were tested and material performance was analyzed. Finite element analysis was performed to determine the heat transferred to and from the user interfaces and the cooking surfaces. This allowed the design to be optimized so that all user interfaces and control systems were at operable temperatures under all scenarios. Additionally, finite element analysis on the structure of the device was performed to ensure the device would not fail when heavy objects were place on top of the system.

IV.A. Heat Transfer from Griddle to Control Components

Heat transfer FEA was performed to determine the heat transfer from the griddle surface to the user interface. This was analyzed to ensure that the griddle did not overheat the electrical components or anywhere the user might interact with the device. Several assumptions were made to set up the analysis. First, it was assumed that the average cooking temperature of the griddle's cooking surface was 400 F and that the temperature across the cooking surface is constant. Additionally it was assumed that the cooking surface is exposed to convection with a convective heat transfer coefficient of 15 W/m^2C. This coefficient of convective heat transfer was chosen to reflect the surface being exposed to free convection with air at 68 F or 25 C. Similarly, it was assumed that the user interface was exposed to convection with a convective heat transfer coefficient of 15 W/m^2C (Engineering Toolbox). The convection was assumed to be between the user interface and air at 68 F or 25 C. Although the surface of the user interface analyzed is usually enclosed, the air for the convection was chosen to have a temperature of 68 F or 25 C, because when implemented the user interface would have a fan that utilized ambient air to cool the components.

In addition to the assumptions above, the analysis was constrained by the materials selected. For heat transfer from the griddle to the user interface, the cooking surface was chosen to be steel with thermal conductivity of 47 W/mC, the housing was chosen to be made of polystyrene with thermal conductivity of 0.033 W/mC, and the user interface was chosen to be made of ABS plastic with a thermal conductivity of 0.188 W/mC. These materials were chosen after preliminary analysis for their insulating properties and also because of the ease of implementing them into fabrication. Figure 38 shows a schematic of the assumptions and constraints.

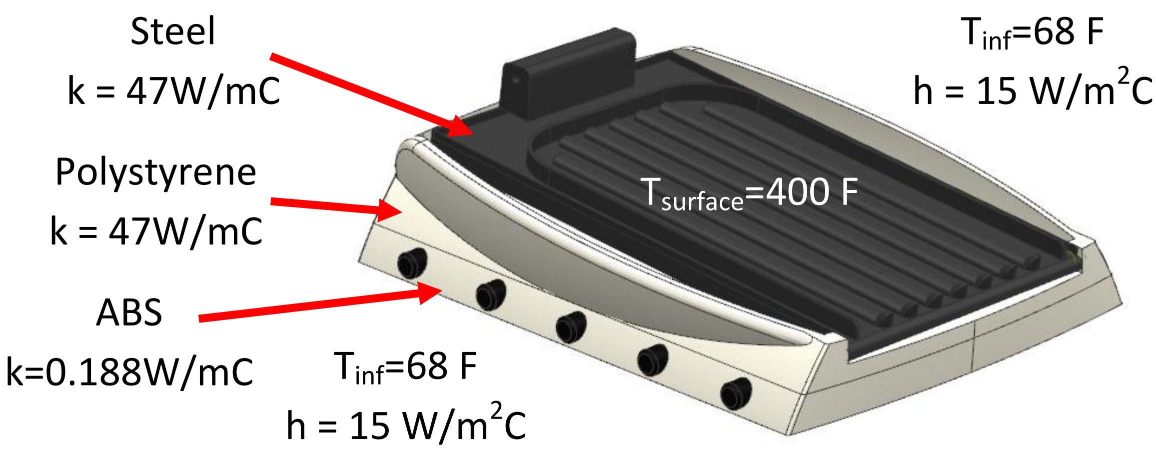


Figure 38. Schematic of Heat Transfer Setup

To perform the FEA, the NASTRAN application in Siemens NX 8.0 was used. First, meshed surfaces with nodes spaced 0.5 inches apart were created for each of the parts in the analysis. All temperature and convection constraints were applied, and the simulation was run. Figures 39 and 40 present the results of the FEA analysis.

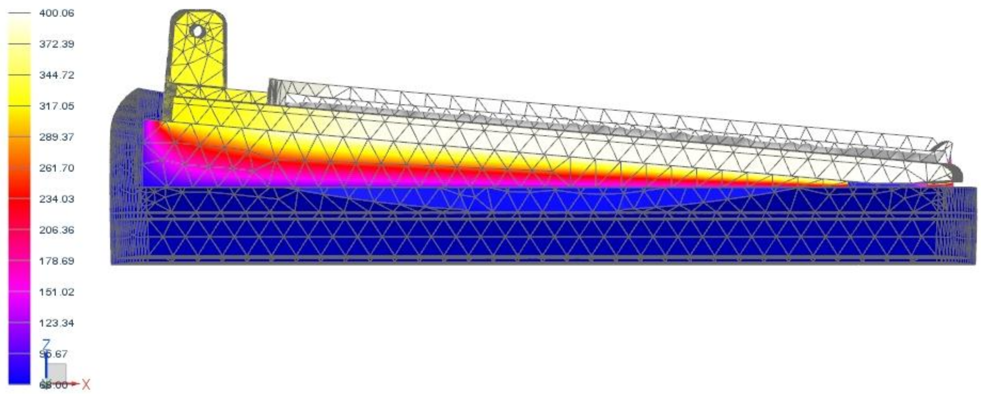


Figure 39. Section View of Heat Transfer FEA along Center Plane of Griddle

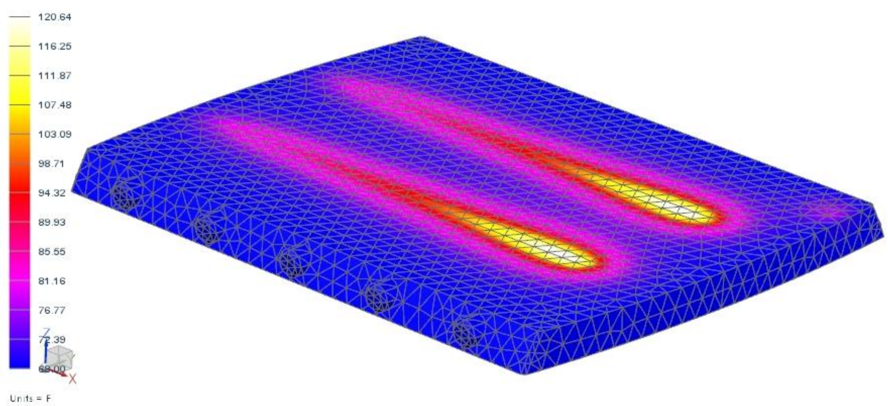


Figure 40. Section View of Heat Transfer FEA of Top of User Interface

From the figures, it can be seen that the user interface never reaches a temperature higher than 120 F, and on average is around 90 F. Thus, the design is appropriate for both electronic components, which must be operated under 150C, and also for human interaction.

IV.B. Heat Transfer from Griddle to Top Housing Surface

Next, a heat transfer analysis was performed on the top griddle to determine the heat transfer from the cooking surface to the handle. Again, it was assumed that the temperture of the griddle was held constant at 400 F, convection occurred on all external surfaces with the convection coefficient being 15 W/m^2C (Engineering Toolbox) and the ambient temperature of air being 68 F or 25 C. The griddle is stainless steel, and the griddle housing is ABS plastic. Figure 41 shows the results of the analyisis

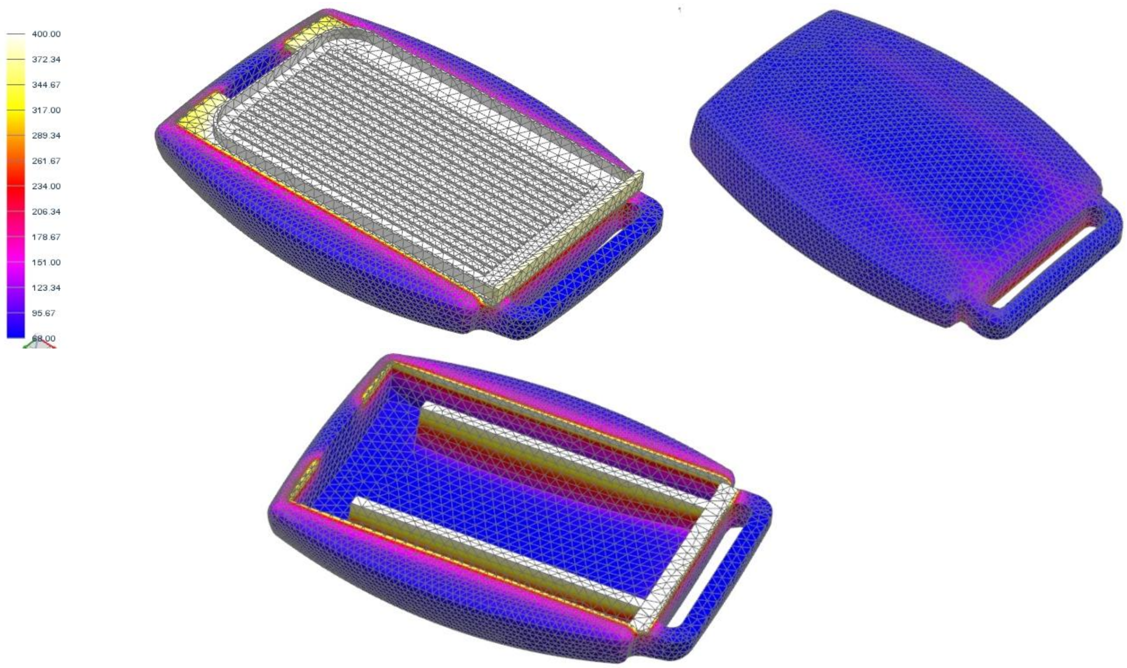


Figure 42. Heat Transfer FEA from Top Griddle to Handle

From the analysis, it is seen that the temperature of the handle remains below 100 F and is safe for the user to operate. Additionally, the analysis shows that the top exterior surface of the griddle housing remains below 120 F. Thus, there is no danger of the exterior surfaces inadvertently damaging its environment with heat.

IV.C. Heat Transfer from Oven to Control Components

Another important analysis that needs to be performed is determining the temperature gradient between the oven and the user interface. The user interface sits on top of the oven and below the griddle. Since all of the electrical components are housed in the user interface portion of the device, it is important that the components do not over heat. Selecting the right material to insult the user interface is critical to the functionality of the Bake & Grill. In order to determine what material should be used to provide the lowest temperature gradient, a finite element analysis using NX Nastran was performed. For simplicity, only the oven was selected as the 3D tetrahedral mesh surface as well as having one heating element. Once the oven was meshed, the material property for the oven was selected to be Aluminum

6061. Next, a constraint of constant temperature selected to be 750°F was placed on the heating element. Convection in the system was idealized by creating a solid that filled the open space in the oven and applying the thermal properties of air to that solid for the analysis. This is a crude idealization, but it provides a worst case scenario of convective cooling. The simulation was then solved to produce Figure 43.

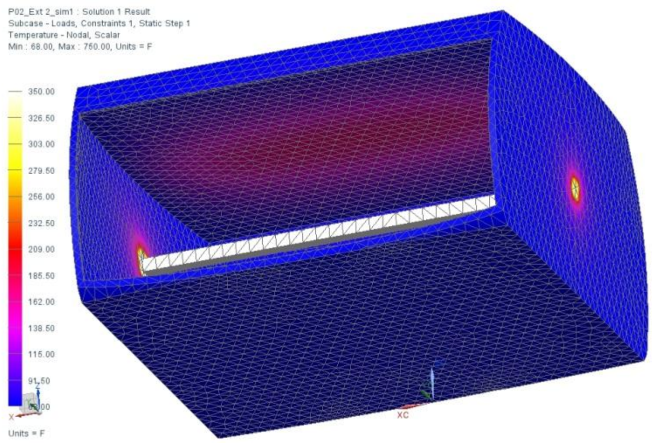


Figure 43 Temperature FEA on oven to user interface

As this figure indicates, the temperature between the oven and the user interface reaches around 209°F without the insulation. The ideal case is to have the temperature to be 150°F and below. To modify the design and reduce the temperature in the user interface control panel, a layer of insulating material such as polystyrene will be added on the top surface of the oven subassembly, which will shield the components from unwanted heat.

V. Verification

In order to verify the results of the NX analysis, hand calculations were performed based on finite element theory for heat transfer.

V.A. Heat Transfer from Griddle to Control Components

The first verification addressed the heat transfer from the griddle to the user interface/control components housing. Figure 44 shows a simplified sketch of the materials between the control components and the bottom griddle.

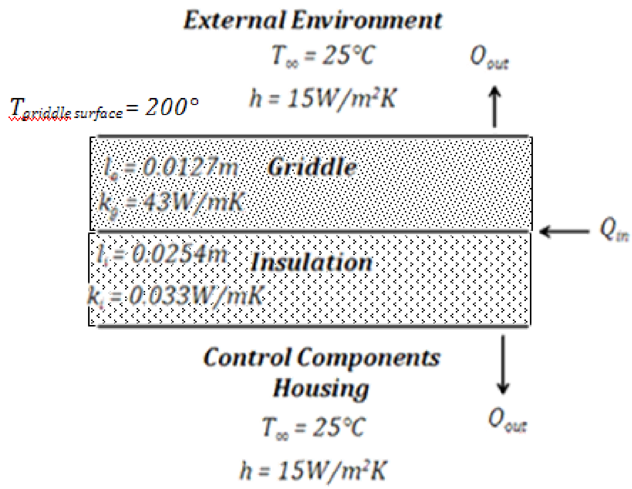


Figure 44. Schematic for Heat Transfer FEA

As shown in Figure 44, the desired temperature of the griddle face is 200 C (400 F) which is the average cooking temperature of a griddle. Additionally, the griddle will be made out of thermally conductive steel and will be insulated from the user interface with an insulating material such as polystyrene. The finite element analysis was performed on this section to determine the heat required to achieve a 400 F griddle temperature and also to determine the temperature that the control components may experience. The driving equation for this FEA is presented in Eq. (1) where Q is the heat into the system, k represents the overall coefficient of heat transfer, and T represents the temperature of the system.

$$Q = k\,[T] \tag{1}$$

The conductive and convective heat transfer in the system is represented by

$$\begin{Bmatrix} Q_{out,griddle} \\ Q_{in} \\ Q_1 \\ Q_2 \\ Q_{out,comp} \end{Bmatrix} = A_s \begin{bmatrix} h & -h & 0 & 0 & 0 \\ -h & h+\frac{k_g}{l_g} & -k_g/l_g & 0 & 0 \\ 0 & -k_g/l_g & \frac{k_g}{l_g}+\frac{k_c}{l_c} & -k_c/l_c & 0 \\ 0 & 0 & -k_c/l_c & \frac{k_c}{l_c}+h & -h \\ 0 & 0 & 0 & -h & h \end{bmatrix} \begin{Bmatrix} T_\infty \\ T_{griddle} \\ T_{insulation} \\ T_{components} \\ T_\infty \end{Bmatrix} \quad (2)$$

For this scenario, the following boundary conditions were applied:

T_∞ = 25° C (Room Temperature)

$T_{griddle}$ = 200° C (~400° F, average cooking temperature)

$Q_1 = Q_2 = 0$ (Heat in = Heat out)

Additionally, thermal properties for steel (k_g = 43 W/m°C) were applied to the griddle and thermal properties for polystyrene (k_c = 0.033 W/m°C) were applied to the insulation. The coefficient of convective heat transfer for free convection of air ranges from 5 to 25 W/m^2°C (Engineering Toolbox), therefore the convection coefficient for this analysis was estimated to be h≈15 W/m^2°C. The thickness of the griddle is given as l_g= 0.5 in = 12.7 mm. The thickness of the insulation is given as l_c= 1 in = 25.4 mm. Finally, the surface area of the section considered is A=145 in^2= 0.0935 m^2.

From these variables, the FEA matrix can be solved for Q_{in} and $T_{components}$ as in

$$\begin{Bmatrix} Q_{out,griddle} \\ Q_{in} \\ 0 \\ 0 \\ Q_{out,comp} \end{Bmatrix} = 0.0935 * \begin{bmatrix} 15 & -15 & 0 & 0 & 0 \\ -15 & 15+\frac{43}{0.0127} & -\frac{43}{0.0127} & 0 & 0 \\ 0 & -\frac{43}{0.0127} & \frac{43}{0.0127}+\frac{0.033}{0.0254} & -\frac{0.033}{0.0254} & 0 \\ 0 & 0 & -\frac{0.033}{0.0254} & \frac{0.033}{0.0254}+15 & -15 \\ 0 & 0 & 0 & -15 & 15 \end{bmatrix} \begin{Bmatrix} 25 \\ 200 \\ T_{ins} \\ T_{comp} \\ 25 \end{Bmatrix} \quad (3)$$

Equation 3 has 5 constraints and 5 unknowns, and the stiffness matrix has a non-zero determinant, thus the unknowns can be solved. From linear algebra, the unknown variables were solved to be:

$Q_{out,griddle}$ = -245 W

Q_{in} = 275 W

$Q_{out,components}$ = -30 W

T_{ins} = 199.9° C

$$T_{components} = 38.97° \text{ C}$$

Thus, with the appropriate thickness of insulation, the temperature of the control components remains at an operable temperature of 38.97° C or 102.14° F. Additionally, to power the griddle at 400° F a power input of 275 W will be required. This is a fraction of the typical toaster oven maximum power, which is typically 1400 W.

V.B. Heat Transfer from Griddle to Top Housing Surface

Next, the heat transfer from the top griddle to the handle and top surface of the housing was evaluated. Figure 45 shows a schematic of the analysis. Notice that the housing uses 0.5 in wide ribs to interface with the griddle. In reality, these ribs would be exposed to convection from the air encased in the housing. But for this analysis convection on the ribs is omitted to determine the worst case temperatures on the housing.

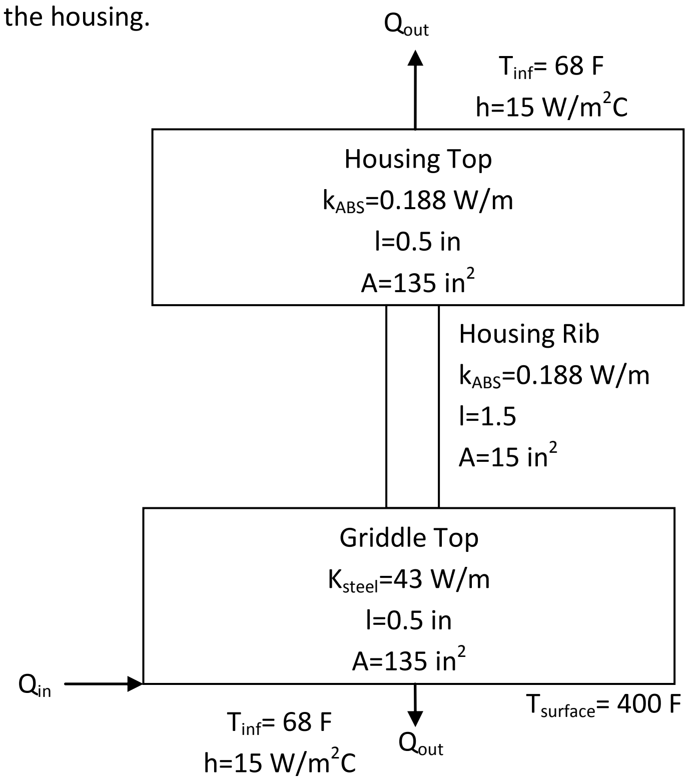


Figure 45. Schematic of Top Griddle

For this analysis, the housing was designated as ABS plastic with 0.5 in wall thickness and a cross sectional area of 135 in^2, while the ribs were also ABS plastic with a length of 1.5 in and a cross sectional area of 15 in^2. Again, the convection coefficient was chosen to be 15 W/m^2°C (Engineering Toolbox) and was applied to the surface of the griddle and the top of the housing. The temperature of the griddle was constrained at 400 F to represent the average cooking temperature, and the material of the griddle was designated as steel with a thickness of 0.25 in and a cross sectional area of 135 in^2.

Equation 4 shows the finite element heat transfer analysis model for the griddle.

$$\begin{matrix} Q_{out} \\ Q_{in} \\ Q_1 \\ Q_2 \\ Q_3 \\ Q_{out} \end{matrix} = \begin{matrix} A_s h & -A_s h & 0 & 0 & 0 & 0 \\ -A_s h & A_s h + A_s \frac{k_s}{l_s} & -A_s k_s/l_s & 0 & 0 & 0 \\ 0 & -A_s k_s/l_s & A_s \frac{k_s}{l_s} + A_r \frac{k_r}{l_r} & -A_r k_r/l_r & 0 & 0 \\ 0 & 0 & -A_r k_r/l_r & A_r \frac{k_r}{l_r} + A_h \frac{k_h}{l_h} & -A_h k_h/l_h & 0 \\ 0 & 0 & 0 & -A_h k_h/l_h & A_h \frac{k_h}{l_h} + A_h h & -A_h h \\ 0 & 0 & 0 & 0 & -A_h h & A_h h \end{matrix} \begin{matrix} T_\infty \\ T_{griddle} \\ T_{rib,1} \\ T_{rib,2} \\ T_{housing} \\ T_\infty \end{matrix} \quad (4)$$

Constants

A_s=135 in^2 *A_r=15 in^2* *A_h=135 in^2*

k_s=43 W/m°C *k_r=0.188 W/m°C* *k_h=0.188 W/m°C*

l_s=0.25 in *l_r=1.5 in* *l_h=0.5 in*

h=15 W/m^2°C

Constraints

Q_1= Q_2= Q_3=0 W

$T_{infintiy}$= 68 F

After solving the equation above, it was found that the surface temperature of the housing was approximately 136.3 F. This temperature corresponds to the NX model and verifies that the griddle is a safe design minimizes temperatures of surfaces that users are exposed to.

V.C. Heat Transfer from Oven to Control Components

Finally, verification on the heat transfer from the oven to the user interface was performed. Figure 46 shows a simplified sketch of the material properties between the user interface and the top of the oven.

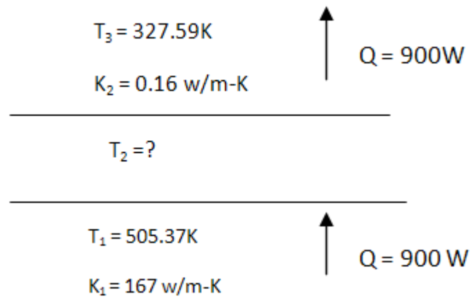


Figure 46 Diagram of 1D conduction

The maximum temperature the grill will be operating at is 450 F. With this high temperature, the material that the electrical components are housed in has to be able to handle a high temperature. The material chosen for the oven for this analysis is aluminum 6061 as well as the insulating material with a relative high thermal conductivity. The finite element analysis was performed on this section to determine the temperature that the control components may experience. The conductive heat transfer in the system is represented by Equation 4.

$$\begin{matrix} \frac{A_1k_1}{L_1} & \frac{-A_1k_1}{L_1} & 0 \\ \frac{-A_1k_1}{L_1} & \frac{A_1k_1}{L_1}+\frac{A_2k_2}{L_2} & \frac{-A_2k_2}{L_2} \\ 0 & \frac{-A_2k_2}{L_2} & \frac{A_2k_2}{L_2} \end{matrix} \begin{matrix} T_1 \\ T_2 \\ T_3 \end{matrix} = \begin{matrix} q \\ q \\ q \end{matrix} \tag{4}$$

For this scenario, the following boundary conditions were applied:

L_1 = 0.25 in

L_2 = 1 in

$A_1 = A_2$ = 48 in^2

From these variables, the FEA matrix can be solved for T_2. By solving this matrix, the following was determined:

$$T_2 = 451° \text{ F}$$

This shows that at the maximum temperature of the oven, the insulation has to be able to handle a temperature of 451° F. The thickness of the oven plays a big role in how much heat is transferred to the user interface. Since oven walls are so thin, heat is easily transferred through them. By creating a thicker layer of aluminum, the temperature will significantly decrease.

VI. Summary and Future Plans

The Bake & Grill demonstrates the possibility of combining an oven and a griddle into a compact cooking solution. The design shows how it would be quite useful and work well for individuals such as college students, RV owners, or tenants of small apartments that do not have space for a full kitchen. The Bake & Grill is unlike any product on the market and is designed to meet the needs of these intended users.

The design utilized a seamless component strategy where all external components were modeled out of one solid body. This provided the Bake & Grill with a sleek aesthetically appealing look and allowed the components to fit together simply. The internal components demonstrated how and where food would be prepared in this device. Analysis on the device demonstrated that most components would operate safely at low temperatures that would not damage internal components or the user. Analysis was also used to help improve future design; in particular the interface between the oven and the control components should be redesigned with insulation shielding the control components from the oven. While the analysis pointed out some design challenges, overall the device is a viable solution capable of being implemented after further detailed design and slight modifications.

VII. Future Plans

The model is a proof of concept to depict how an oven and a griddle would be implemented into a compact design. While the features modeled are realistic in dimensions and shape, more detailed design is necessary to ensure components interface with each other and move appropriately. Moreover, further finite element analysis should be performed on the model to better understand the heat transfer in the system. Specifically, convective properties should be taken more into account and the appropriate NASTRAN application should be used to evaluate the forced convection of the oven. Moreover, a FEA model as a function of time should be rendered in order to determine how quickly the device will perform its functions. Finally, future designs must incorporate more design for manufacturability and assemblability concepts. The device has a lot of components, and it is critical to be able to produce them cheaply and assemble them effectively. After optimizing the design, the Bake & Grill will be ready for production and off to the market.

VIII. References

"Convective Heat Transfer." *The Engineering Toolbox*. Web. 26 Apr. 2013.

<http://www.engineeringtoolbox.com/convective-heat-transfer-d_430.html>