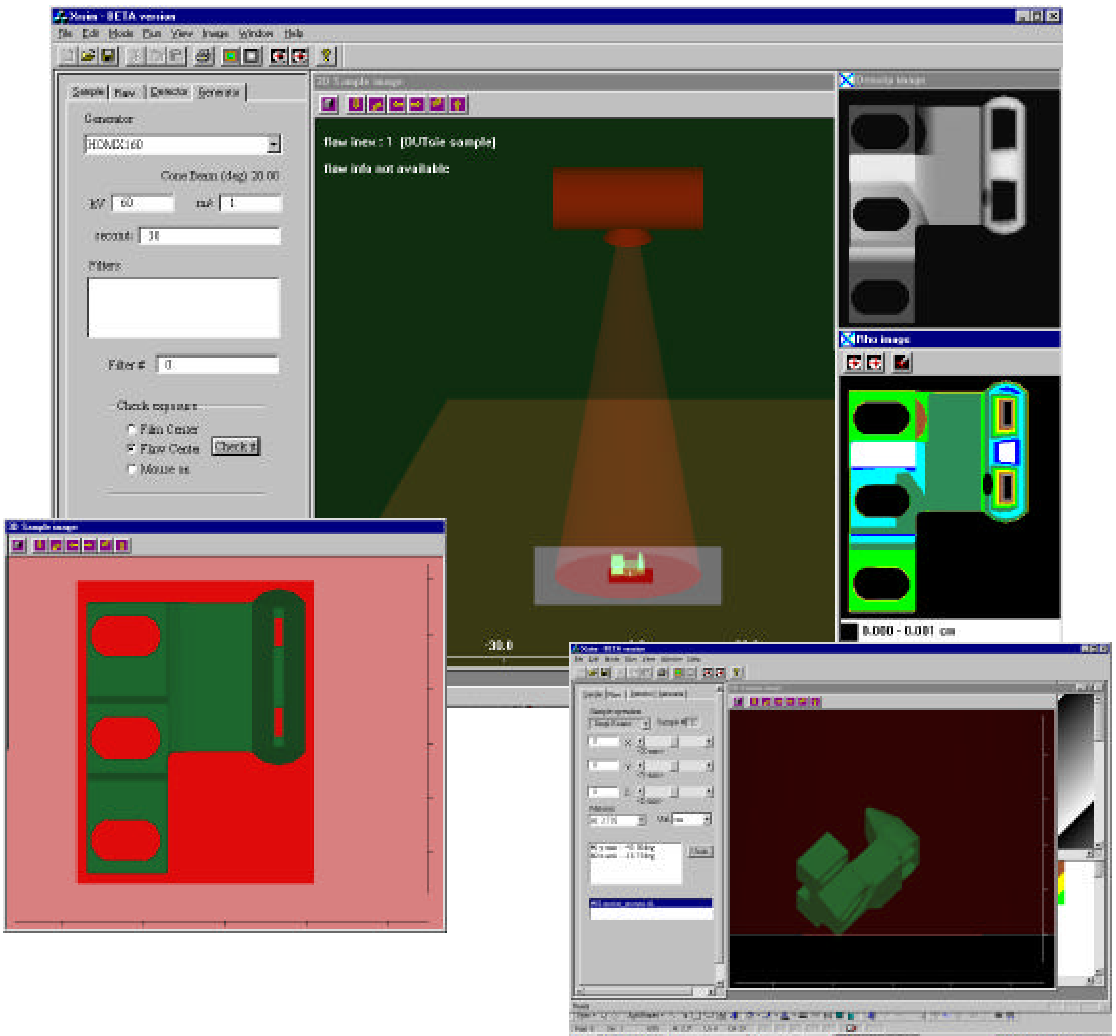
XRSIM

USERS MANUAL



Center for Nondestructive Evaluation
Iowa State University
4/99

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INTRODUCTION TO THE X-RAY SIMULATOR (XRSIM)

The X-ray simulator (XRSIM) program was designed and developed at Iowa State University's Center for Nondestructive Evaluation. The program simulates radiographic inspections using a computer aided design (CAD) model of a part to produce physically accurate simulated x-ray radiographic images. The program allows the operator to select different parts to inspect, adjust the placement and orientation of the part to obtain the proper equipment/part set-up, and adjust all the usual x-ray generator settings to arrive at the desired radiographic film exposure.

Successful radiography depends on numerous variables that affect the outcome and quality of an image. Many of these variables have a substantial effect on image quality and others have little effect. Using the XRSIM program the inspection variables can be modified and the resulting image viewed and evaluated to assess the impact that these variables have on the image. Many inspection scenarios can be rapidly modeled since the shot set-up and exposure can be quickly accomplished and the film-developing step is eliminated. The almost instantaneous results are especially valuable in education and training settings. Not only can a greater number and variety of problems be explored, but also the effects of variables can be learned by self-discovered through experimentation, which is one of the most effective modes of learning. Also, the results are not complicated by unnecessary variable such as film processing artifacts, and many of the distractions unrelated to the primary learning exercise (that can confuse the results and even the purpose of the exercise) are eliminated. Using the program, a more effectively understanding of the scientific concepts associated with radiography will be developed.

Another important aspect of the program is that it does not require a real part for the inspections. Inspections can be simulated that would otherwise be impossible or too costly to perform outside of the computer environment. Flaws of various shapes and sizes can be easily introduced into the CAD model to produce a sample set for probability of detection exercises. Caution must be used when applying the results, as densities produced in the simulated images may not match exactly the images produced in the laboratory using similar equipment settings. The difference between the actual and simulated radiographs is primarily due to approximations made in the scattering model in XRSIM. To keep the computation times reasonable, we have simplified this part of the model. As scattering effects become more dominant, for example a 1" steel sample at 250 kVp will have over half of the total flux reaching the detector be due to scattering, the predicted density will agree less with the actual density on the radiograph.

The XRSIM program has been designed to run in a Windows® environment on an IBM or IBM compatible, Pentium II computer. It is assumed that the user is familiar with the Windows® operating system and its standard features such as pull-down menus and toolbar buttons. These instructions will explain the basic steps for producing an image using the program.

STEPS FOR PRODUCING SIMULATED RADIOGRAPH

The steps required to produce a simulated radiograph using XRSIM are basically the same as those required to produce a true radiograph. The only required extra step involves generating a 2D-thickness map of the part CAD file once the part has been positioned and oriented as desired in the simulated x-ray vault space. A second extra step that may be included in the XRSIM procedure is to introduce a flaw into your sample (flaws are optional when using XRSIM). The steps required to produce a simulated radiograph are:

1. Open the XRSIM program.
2. Select a sample (CAD file) to radiograph.
3. Position and orient the sample relative to the film and x-ray tube.
4. Select the material of the sample.
5. Introduce a flaw into the sample, if required.
6. Run the CAD function to produce a 2D-thickness map of the sample.
7. Select the desired film.
8. Resize and reposition the film to image the desired area of the sample.
9. Select the x-ray generator to be used.
10. Set the Kilovoltage, amperage and exposure time of the generator to the settings required producing the desired radiographic image.
11. Run XRSIM (expose the film) to produce the simulated radiograph.

These instructions are broken into two sections. The first section covers the basic operation of required to produce an image. The second section covers some of the less used features of the program. Topics covered in this second section include:

1. Working with multiple samples and flaws
2. Resizing the sample.
3. Modifying the resolution of the image.

It would be best to use this introduction along with the simulation package. Understanding of system operation will come much quicker if the user explores the program while reading the manual.

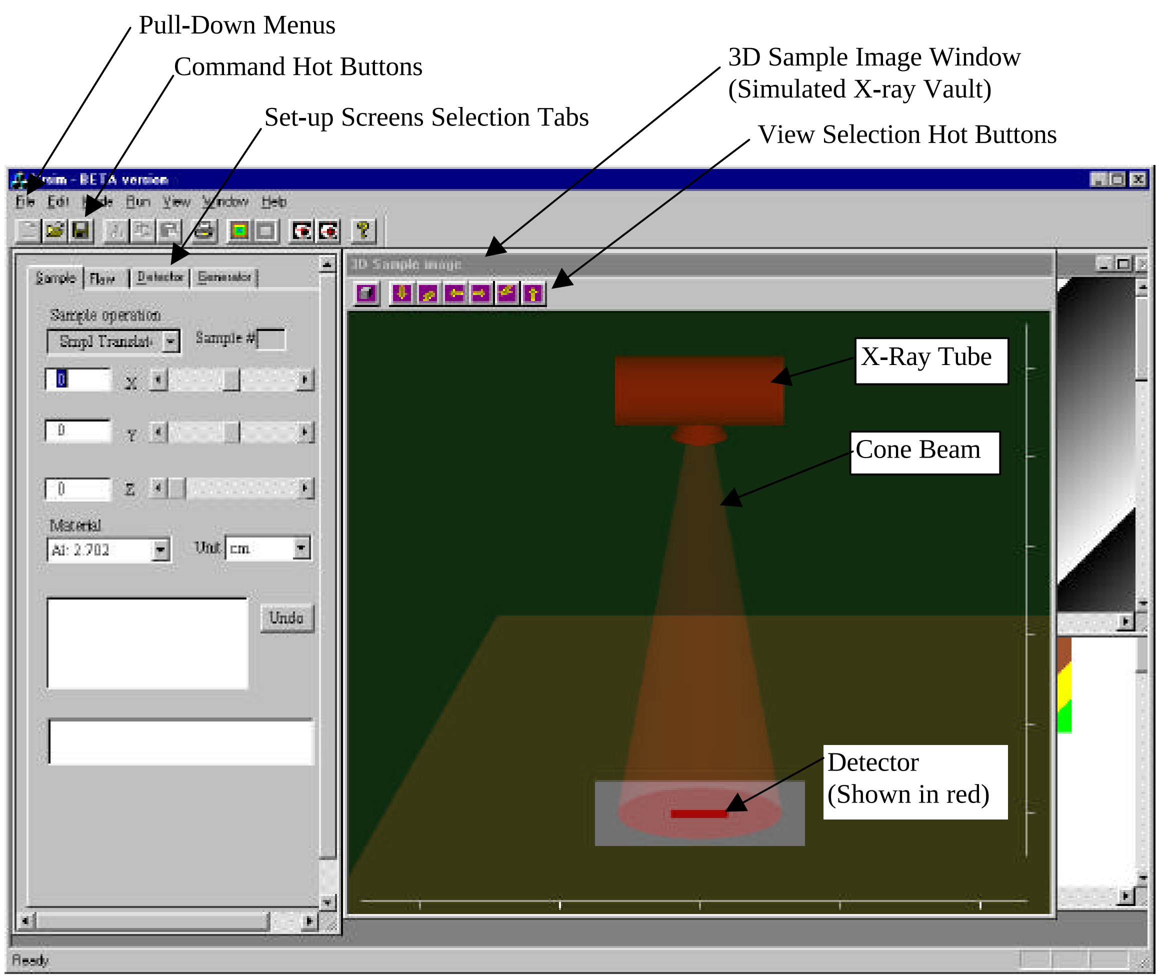
SECTION 1- BASIC OPERATIONS

OPENING THE XRSIM PROGRAM

1. Find the **XRSIM.exe** program file on the computer.
2. Double click on the **XRSIM** icon.

FINDING YOUR WAY AROUND IN XRSIM

When the program opens, you will see the screen below. At the top of the main window you will pull-down menus and command hot buttons that function the same way they do in any Windows® environment. The command hot buttons provide shortcuts for most of the highly used commands found in the pull-down menus. The controls used to select and modify the sample, flaw, detector, and the generator are separated into four set-up windows. The desired set-up window can be displayed by clicking on the selection tabs provided for each of the windows.



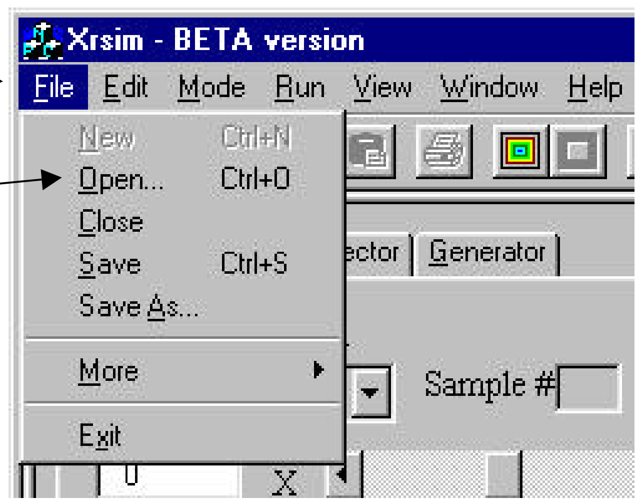
Choosing a Sample (CAD File of Part)

When the program opens, the set-up window **Sample** tab will be selected and the **Sample** set-up window will be displayed and active. The first action required is to open the sample CAD file selection window and choose a sample to inspect.

1. In the upper left corner of the screen, choose **File** and then **Open** (or use the file open hot button).
2. You will see a number of part CAD files that may be selected. Double click the motor_mount.stl file or select the file and click on the **Open** button.
3. The selected sample will appear in the **3D Sample Image** window.

Choose **File**

Then choose **Open**

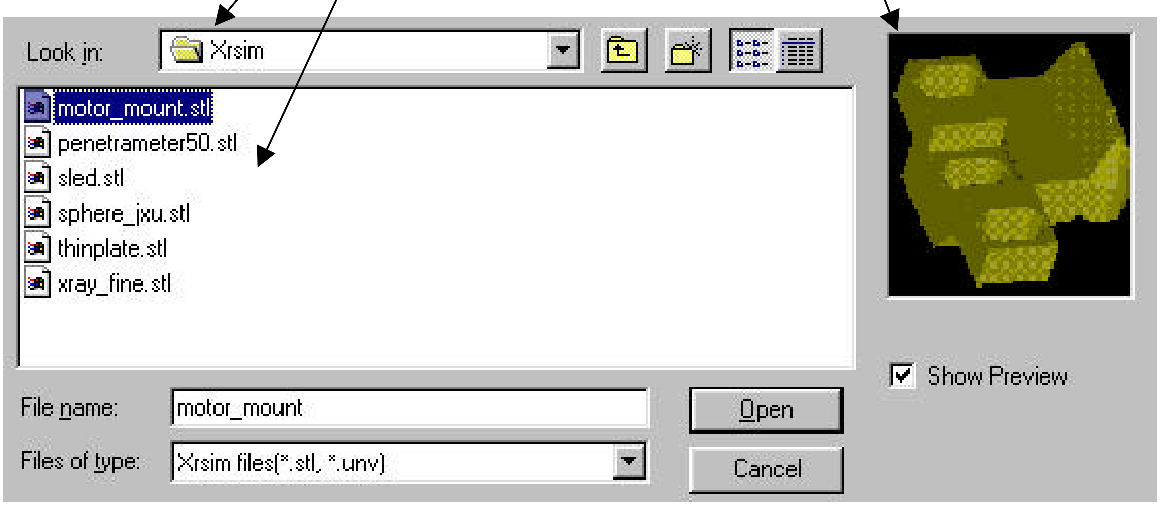


The Part CAD file selection window (shown below) will open.

Directory being looked in for files

List of CAD files

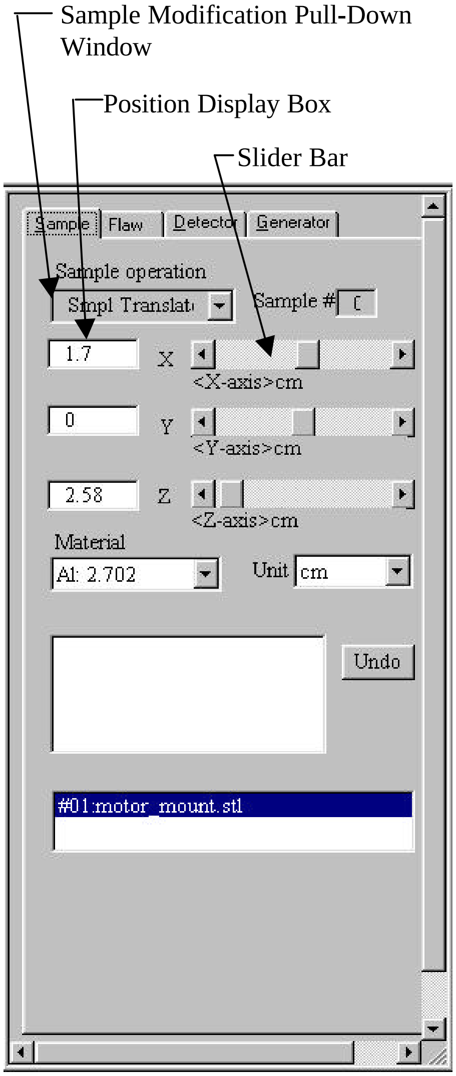
Preview of selected CAD file



POSITIONING THE SAMPLE

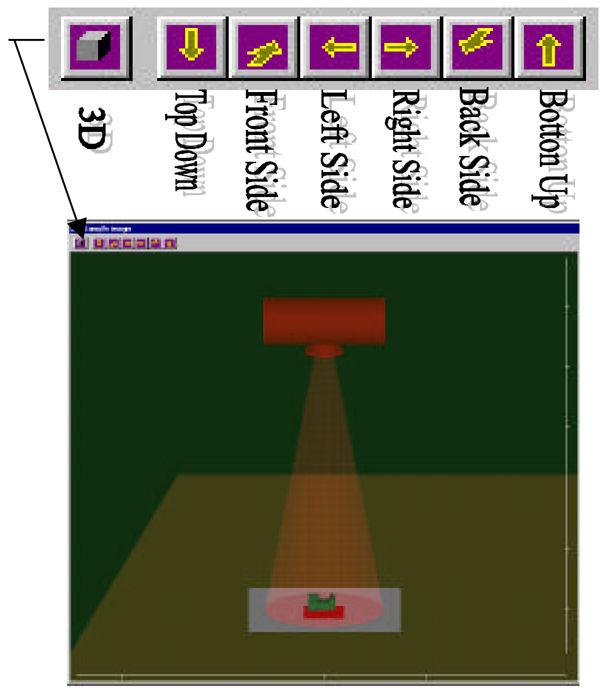
Once a part is brought into the program, it must be positioned and oriented properly in relation to the x-ray source and the film just as would be required in the x-ray vault. The part will appear green in the **3D Sample Image** window as shown on the right below.

1. Use the view selection tabs at the top of the **3D Sample Image** window to display the part from different views. The part can be viewed in 3D, from the front or back, from the right or left side, and from the top or bottom.
2. The part can be moved in any of three ways. First, the part can be moved by clicking and dragging it in any view. The part will not track as fast as the mouse so stop occasionally to let the part catch-up with the mouse pointer. The part can also be moved typing a number in the position display box (the change takes effect when the enter key is depressed) or by using the slider bar or arrows.

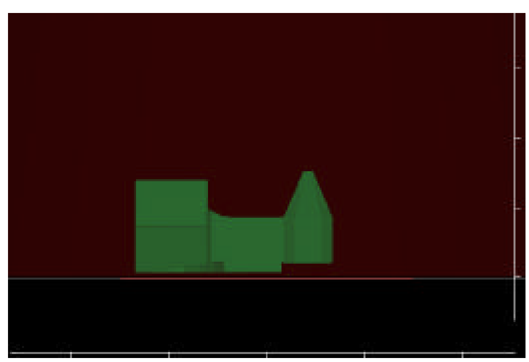


Sample Set-up Window

View Selection Buttons



3D Sample Image View



Front View

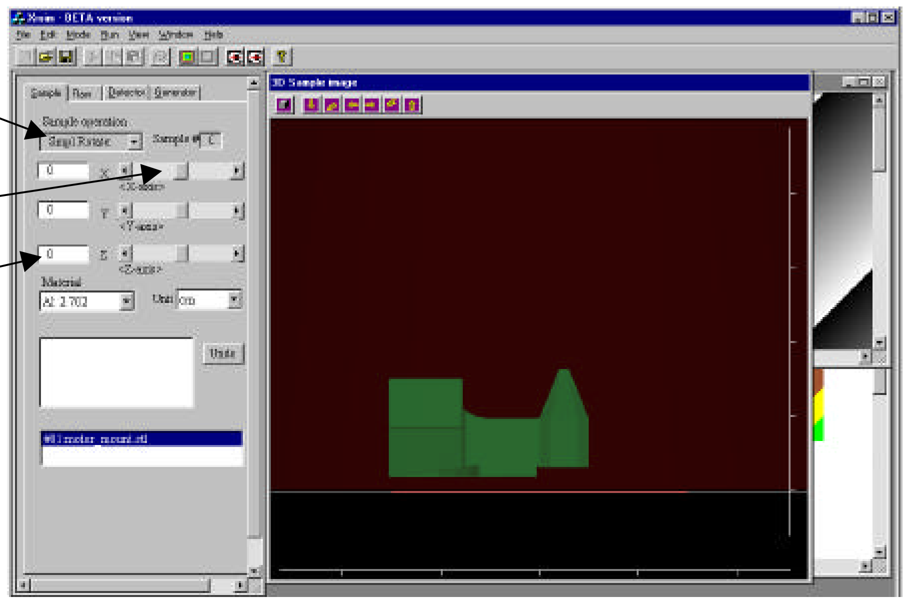
ORIENTING THE SAMPLE

The orientation of the part can also be modified in the Sample set-up window.

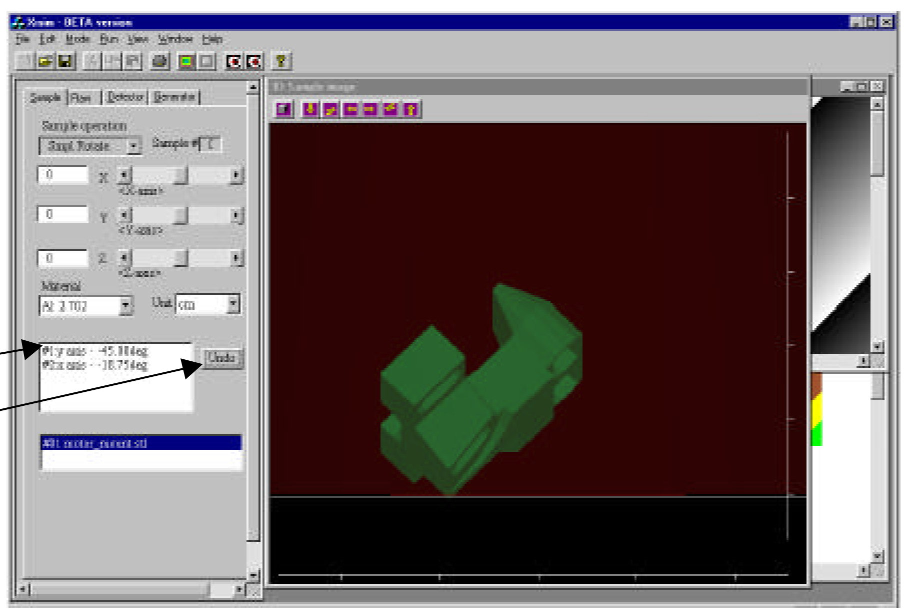
1. In the **Sample** set-up window, choose **Smpl Rotate** in the **Sample operation** input box.
2. Use the slider bars to change the orientation of the sample. When looking at the sample from the front view, the x slider will rotate the sample about an axis that runs left/right, the y slider will rotate the sample about an axis that runs in/out of the screen, and the z slider will rotate the sample about an axis that runs up/down.
3. Any rotation can be easily undone by selecting the operation and clicking the **Undo** button

Select **Smpl Rotate**

Rotate the sample using the slider bars or by typing in a numerical value (in degrees).



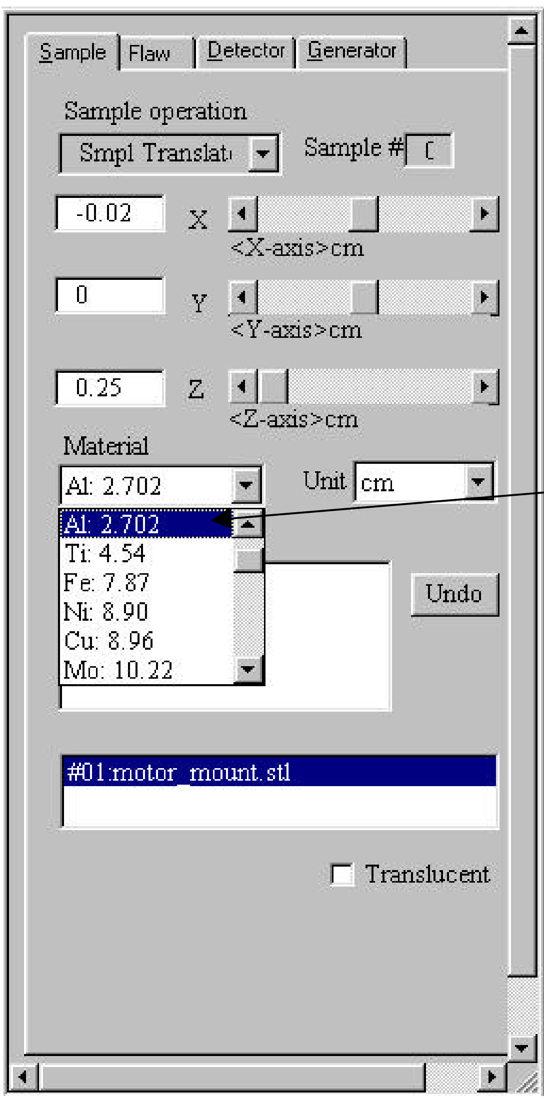
Any of the rotation steps can be undone by selecting the desired step and clicking on the **Undo** button.



CHOOSING THE MATERIAL FOR THE SAMPLE

Two factors effect the interaction of the part with the incident x-ray beam, the material of the part and the density of that material. Lead attenuates a photon of any energy more than aluminum, indicating the effect of the makeup of the atomic number of the material. The attenuation coefficient for a particular energy increases as the fifth power of the atomic number, namely, Z^5. For some materials, for example, ceramics, the composition of the ceramic material does not change, but the density does. In the case of ceramics, a green state material may have a density of only 60% of the fully fired state. In this case, the linear absorption coefficient scales linearly with the density of the material.

1. Locate the **Material** dialog box near the left-center of the sample window. Select the desired material for the part from the materials listed in the dialog box. The material density (in grams per cubic cm) is provided for each of the materials listed. The materials are further described in Appendix A.



Select the desired material for the sample **Material** dialog box on the sample set-up window

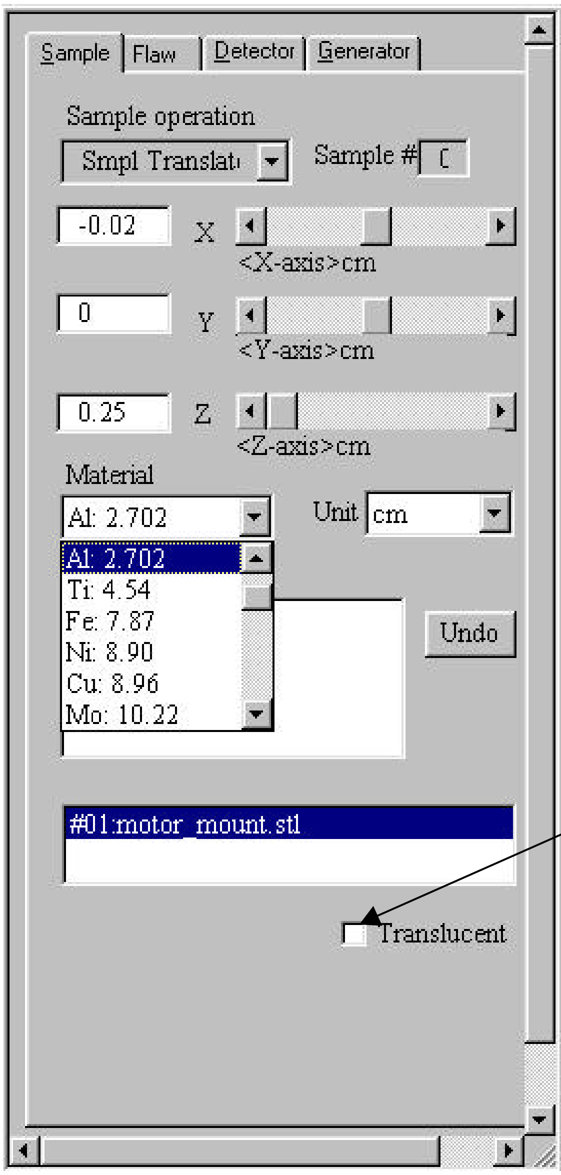
Click on the arrow to display the list of materials available.

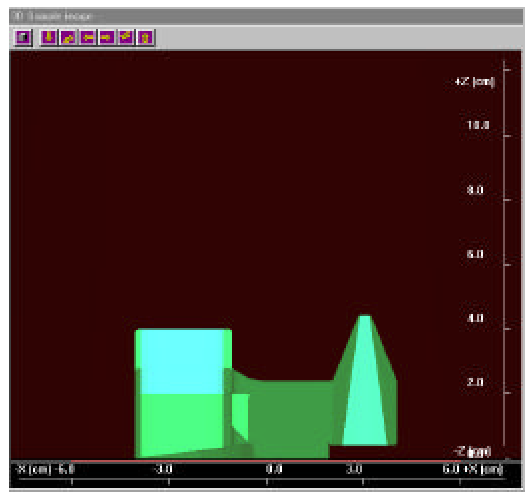
Click on a material to make a selection.

DISPLAYING THE PART IN THE TRAMSPARENT MODE

The part is normally displayed as a solid 3D model. There are times when displaying the sample in a translucent mode is useful. One of these times is when positioning a flaw in the sample. Using the translucent mode allow the flaw to be seen so it can be imbedded below the surface of the sample.

1. The sample can be displayed in the translucent mode by checking the **Translucent** box near the bottom of the sample window.





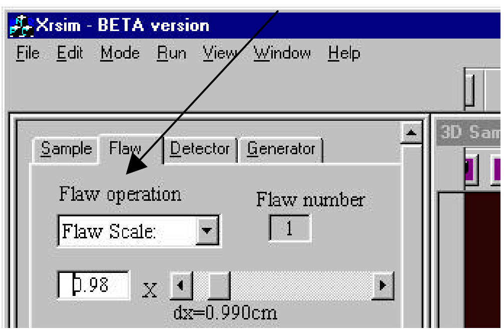
Display the sample in the translucent mode as shown above by checking this box

ENTERING A FLAW INTO THE PART

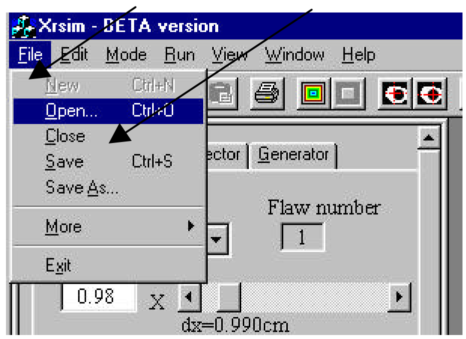
If desired, a flaw may be introduced into the sample. The flaw is a CAD model file (like the sample) so that any flaw configuration can be modeled in the program. Several flaw CAD files of basic shapes, such as a sphere and half sphere, are furnished with the program. These flaws can be resized to roughly represent some of the common material flaws such as voids, semi-circular cracks, and delaminations.

1. Click on the **Flaw** tab to select the flaw set-up window.
2. Open a flaw in the same manner that the sample was opened. In the upper left corner of the screen, choose F**ile** and then **Open** (or use the file open hot button).
3. You will see a number of flaw CAD files that may be selected. These files have a **flw** extension. Double click the **sphere.flw** or select the file and click on the **Open** button.
4. The selected flaw will appear in the **3D Sample Image** window.

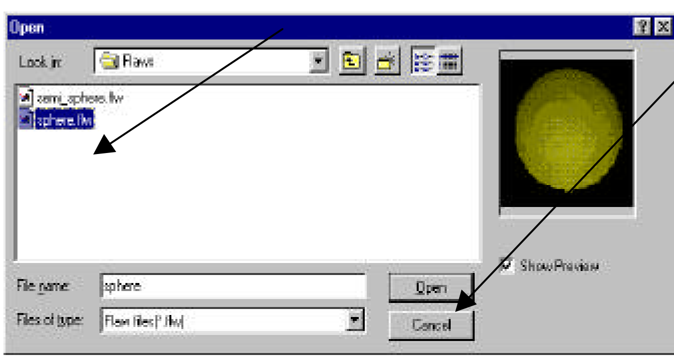
Select the **Flaw** set-up screen

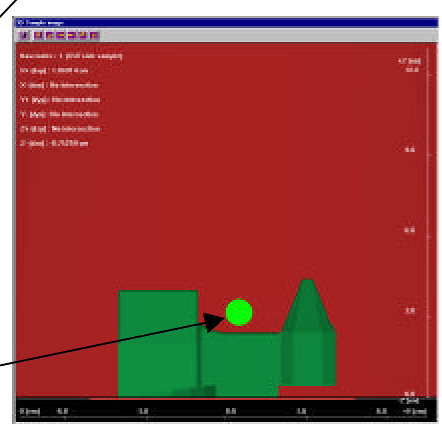


Select **File** then select **Open**



Double click on a flaw file or select the file and click **Open**





The flaw will appear in the **3D Sample** Window (front view shown in light green. The location of the flaw from the boundaries of the part is given in the upper left-hand corner of the window.

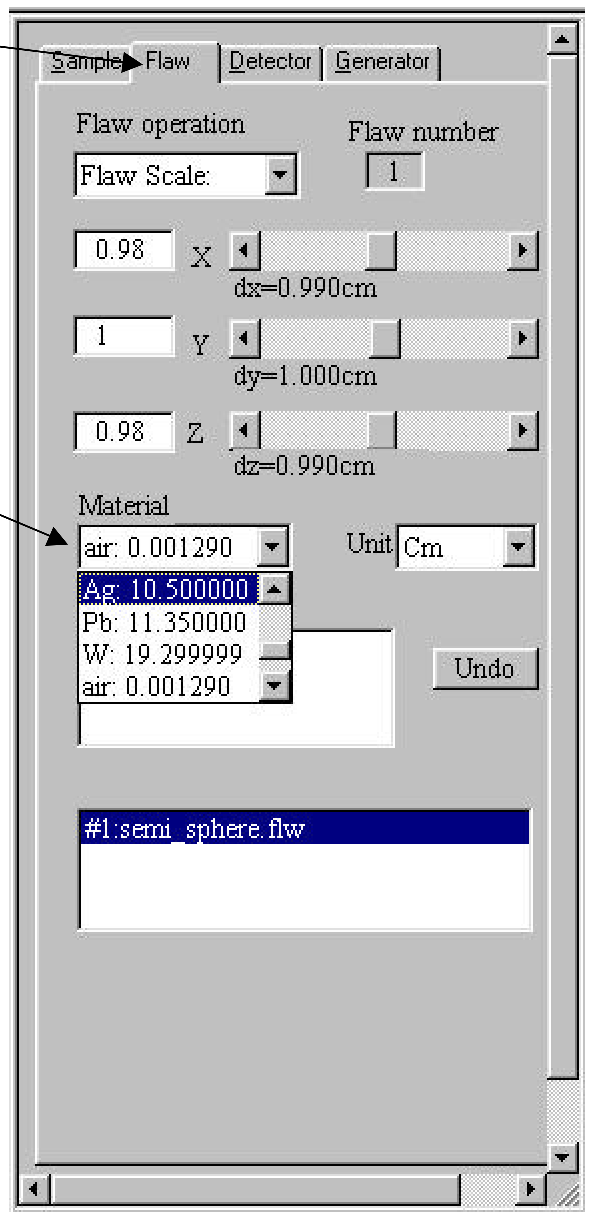
Choosing a Material for the Flaw

Just like the sample, the flaw can be modeled as any number of materials. Materials representing a variety of densities are available for selection as the flaw material. These materials include air to represent cracks and voids in the part, and a variety of high and low-density materials to represent inclusions. The materials are further described in Appendix A.

1. Locate the **Material** dialog box near the left-center of the **Flaw** window.
2. Select the desired material for the part from the materials listed in the dialog box. The material density (in grams per cubic cm) is provided for each of the materials listed.

Make sure the **Flaw** tab is selected

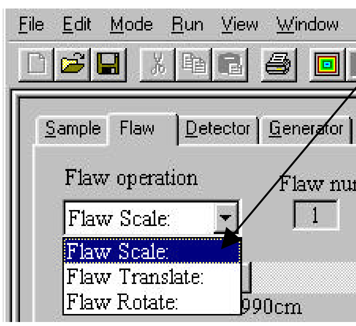
In the **Material** selection dialog box, select the desired material



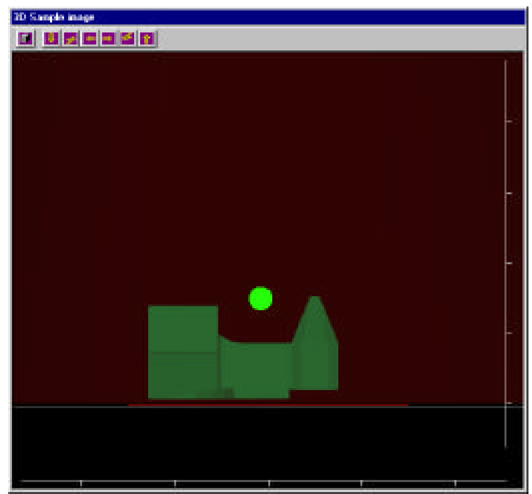
SIZING THE FLAW

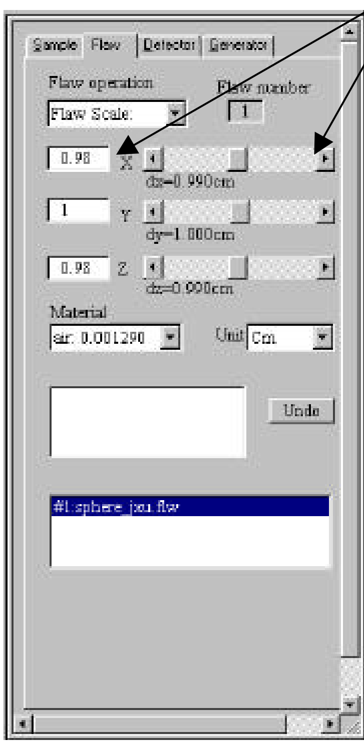
Once a flaw is brought into the program, it must be sized, positioned and oriented properly in the sample. It is usually easiest to size the flaw first, before it is placed in the sample. A flaw such as a sphere can be resized to represent a delamination by making one of the dimensions very small.

1. Use the view selection tabs at the top of the **3D Sample Image** window to display the flaw from desired view.
2. In the flaw set-up window, choose **Flaw Scale** in the Flaw Operation dialog box.
3. The flaw can be sized by typing a value in the flaw size dialog box (the change takes effect when the enter key is depressed) or by using the slider bar or arrows to change the flaw value. A dialog box and slider bar is provided for each of the three dimensions of the flaw. Therefore, to reduce the size of a flaw such as a void (sphere) without changing its shape, the flaw must be scaled equally in all dimensions.



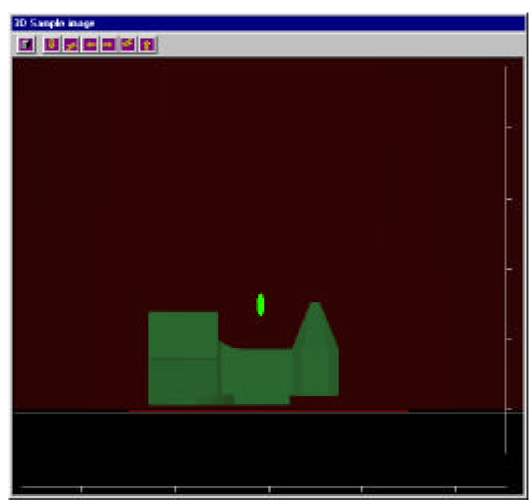
Choose **Flaw Scale** in the **Flaw operation** dialog box in the **Flaw** set-up window





Enter a value in the dialog box or use the slider bar to scale the flaw in the desired dimension

Reducing the value of the **X** dimension, will change the shape of the flaw shown above-right to that shown below-right



ORIENTING THE FLAW

The flaw is oriented in the same manner that the sample.

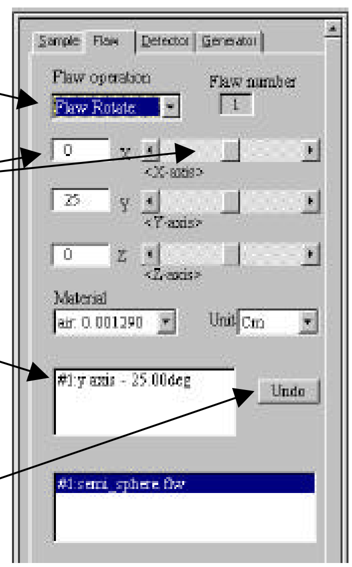
1. Select the **Flaw** tab to display the flaw setup window
2. Select **Flaw Rotate** in the **Sample Operation** dialog box
3. Type a numerical value in the dialog box and hit the enter key or use the slider bars to change the orientation of the flaw. When looking at the flaw from the front view, the x slider with rotate the flaw about an axis that runs left/right, the y slider will rotate the flaw about an axis that runs in/out of the screen, and the z slider with rotate the flaw about an axis that runs up/down.
4. A rotate operation can be undone by highlighting the operation in the dialog box next to the undo button and click on the **undo button**.

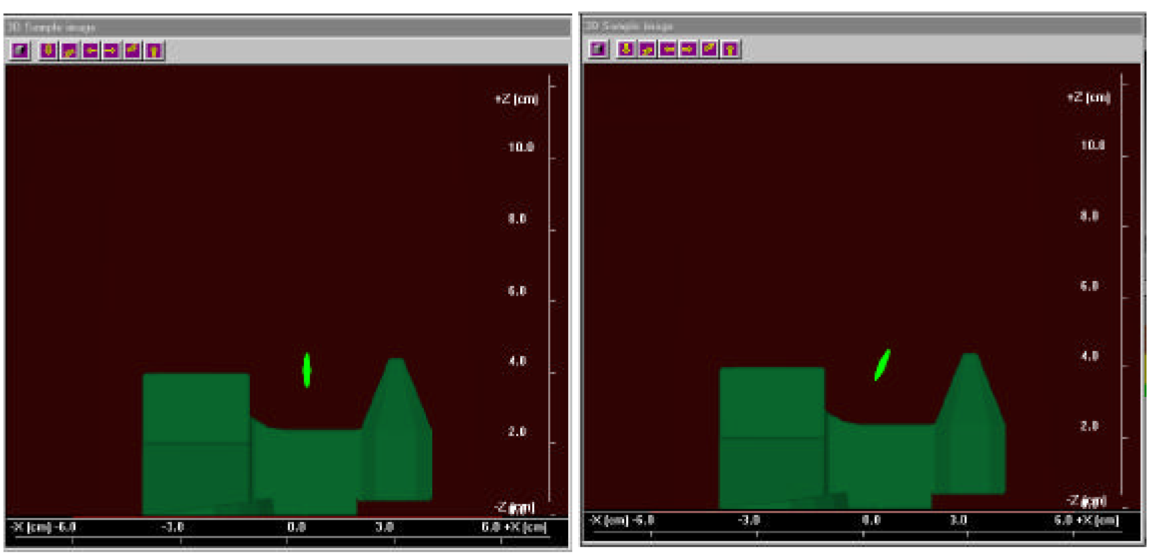
Select **Flaw Rotate** in **the Flaw Operation** dialog box.

Enter a numerical value or use the slider bar to rotate the flaw.

The completed rotation operation will be listed in this window.

A rotate operation can be undone by selecting the operation and clicking on **Undo.**



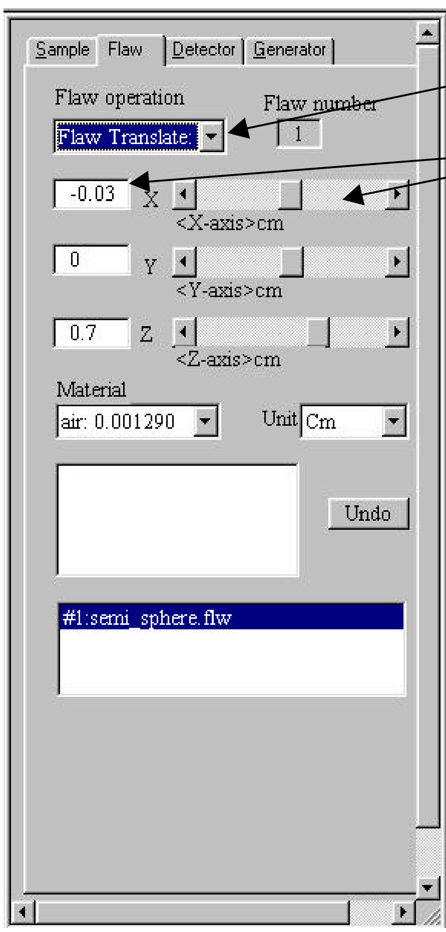


The flaw in the right image has been rotated 25 degrees.

POSITIONING THE FLAW

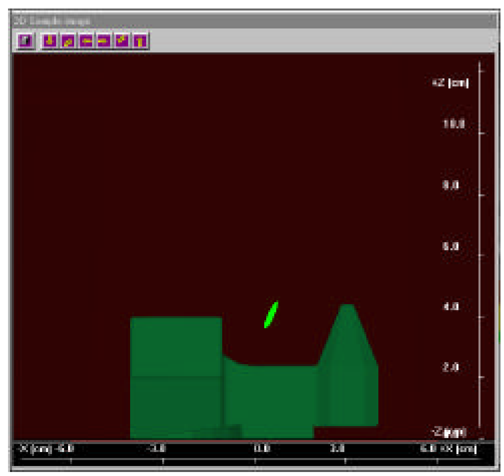
Once the flaw has been sized, it can be positioned and orientated in the part. In some cases, it may be necessary to switch back and forth between positioning and rotating the flaw to achieve proper placement.

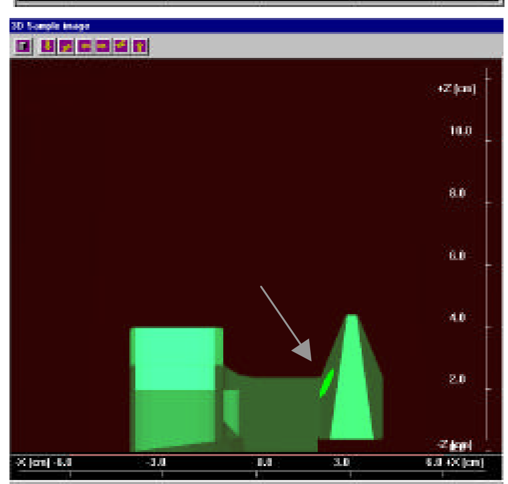
1. Select the **Flaw Translate** option in the **Flaw Operation** dialog box in the flaw set-up window.
2. The flaw can be moved in any of three ways. First, it can be moved by clicking and dragging it in any of the view windows. The flaw will not track as fast as the mouse so stop occasionally to let the flaw catch-up with the mouse pointer. The flaw can also can also be moved typing a number in the position dialog box (the change takes effect when the enter key is depressed) or by using the slider bar or arrows.



Select **Flaw Translate** in the **Flaw Operation** dialog box

Type a numerical value in the entry box or use the slider bar to move the flaw to the desired location.



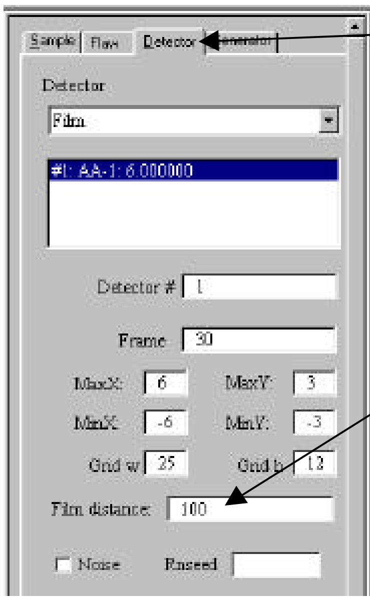


The flaw in the upper image has been moved down into the sample in the lower image. The sample in the lower image is displayed in the transparent mode so the flaw is visible.

SETTING THE SOURCE TO FILM DISTANCE

Once the sample is configured as desired in the x-ray vault, the distance of the source to the film should be set.

1. Select the **Detector** tab to display the detector set-up window.
2. In the **Detector** dialog box select the desired detector.
3. Set the source-to-film distance by typing in a value in the **Film distance** dialog box and press the enter key. The default value is 100 cm.



Select the **Detector** tab

Enter the desired source-to-film distance (in cm) in the **Film distance** box and press the enter key.
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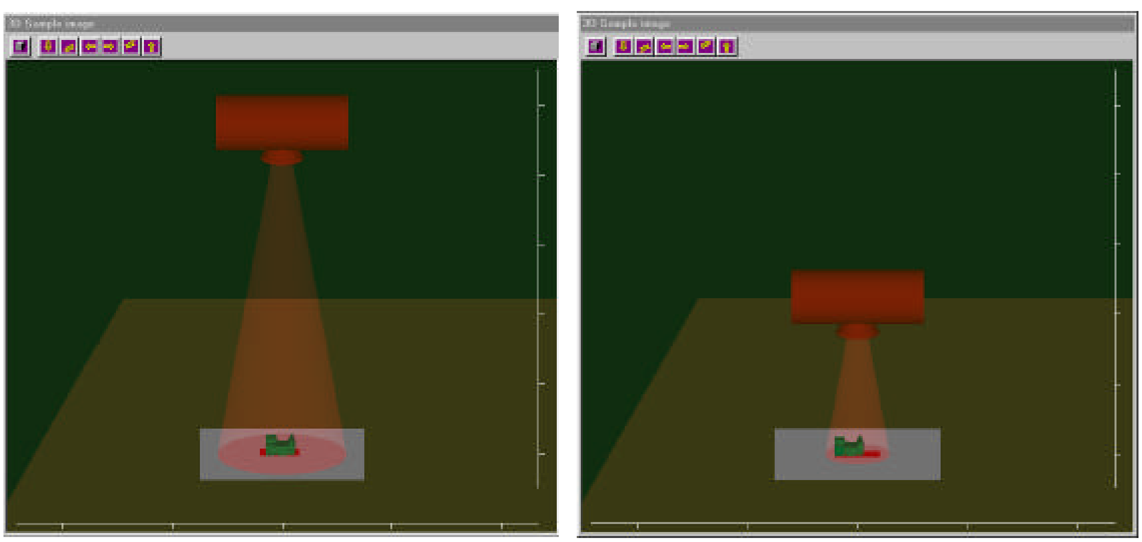
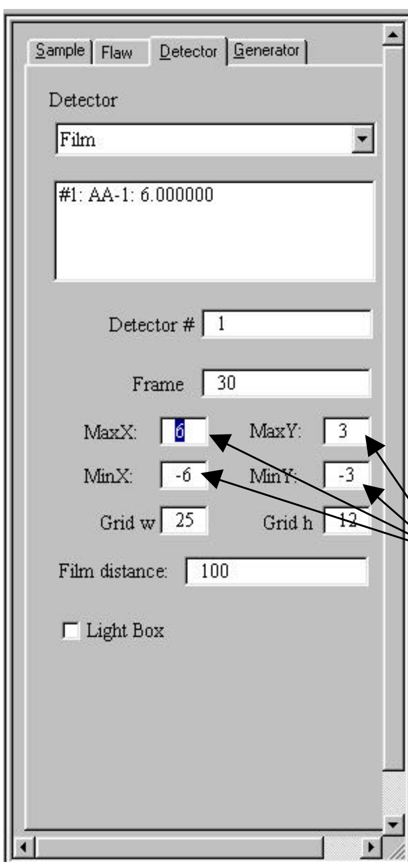


The Film to source distance in the left image is 100 cm and it has been changed to 50 cm in the right image. Note that the x-ray tube has moved closer to the film and the cone beam projection is smaller

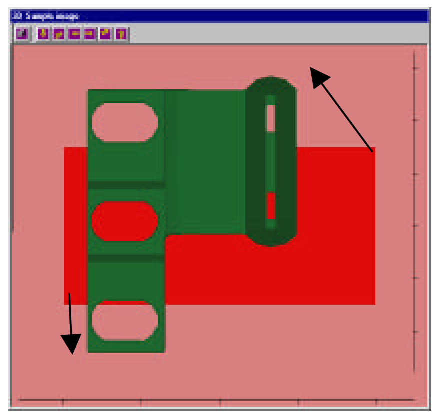
SIZING AND POSITIONING THE FILM

Once the part has been placed in its desired position between the x-ray tube and the film, the film may need to be resized and repositioned to image the area of interest.

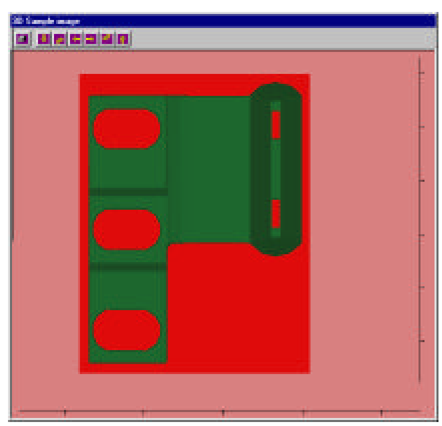
1. Select the top view (down arrow above the x-ray tube) for a view looking down from the x-ray tube. You will notice two things: the film (in red) is not entirely under the part and the cone of the x-ray beam (in pink).
2. The film can be resized by clicking on the corner of the film and drag the corner to change the size and shape of the film. The film and also be resized by typing numerical values in the **MaxX**, **MinX**, **MaxY**, and **MinY** boxes on the **Generator** set-up window.
3. The film can be moved without changing its size by clicking on it away from the corners and dragging it to the desired location.
4. Now click on the second arrow above the x-ray tube and you will see a side view. The line represents the film plane. You will need to click and drag the part until it is even or slightly above the film plane. Looking at the left window you will see the numbers for your X, Y, Z positions have changed. **NOTE**: **when moving the part or film, give the system time to keep up as the system will continue moving after you stop the mouse**. Return to the top view to confirm you have not moved the part off the film.



Clicking on the corner of the film and dragging as shown by the arrows in top right figure will change size and position of film to that shown in the bottom figure.



The film size and position can also be changed by entering numerical values. The values reflect the film edge distance from the center of the x-ray beam.



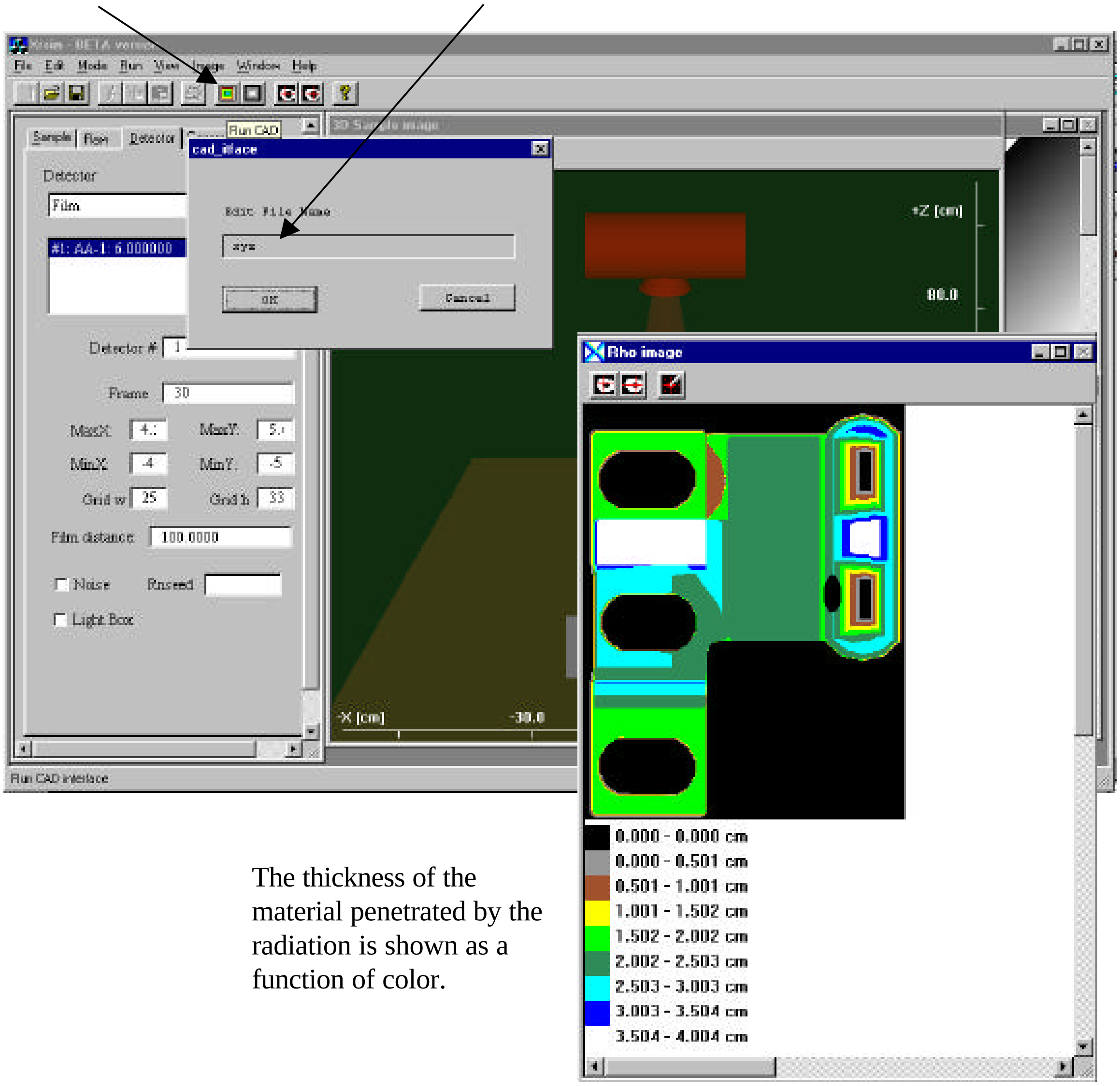
GENERATE THE 2D THICKNESS MAP FROM THE CAD FILE

Once the sample, the x-ray tube and the detector have been configured inside the vault, a 2D-thickness map must be generated of the part from the CAD file. This step determines the amount of material that the x-rays must travel through based on the configuration of the sample and the flaw. This thickness map is calculated over the size of the detector so this operation must be completed after the part, source, and film are set. If any changes are made to the set-up, the 2D-mapping step must be repeated.

1. Run the CAD 2D thickness mapping procedure by clicking the **Run Cad** hot button or by selecting **Cad** in the **Run** menu.
2. Edit the file name in the pop-up box to save the 2D-thickness map. If the file name is not changed, the file will be overwritten the next time this procedure is preformed.
3. The 2D image of the part showing thickness of the material that the x-ray beam will travel though will be displayed.

Click the **Cad Run** hot button.

Enter a new file name (if desired) and click **OK**

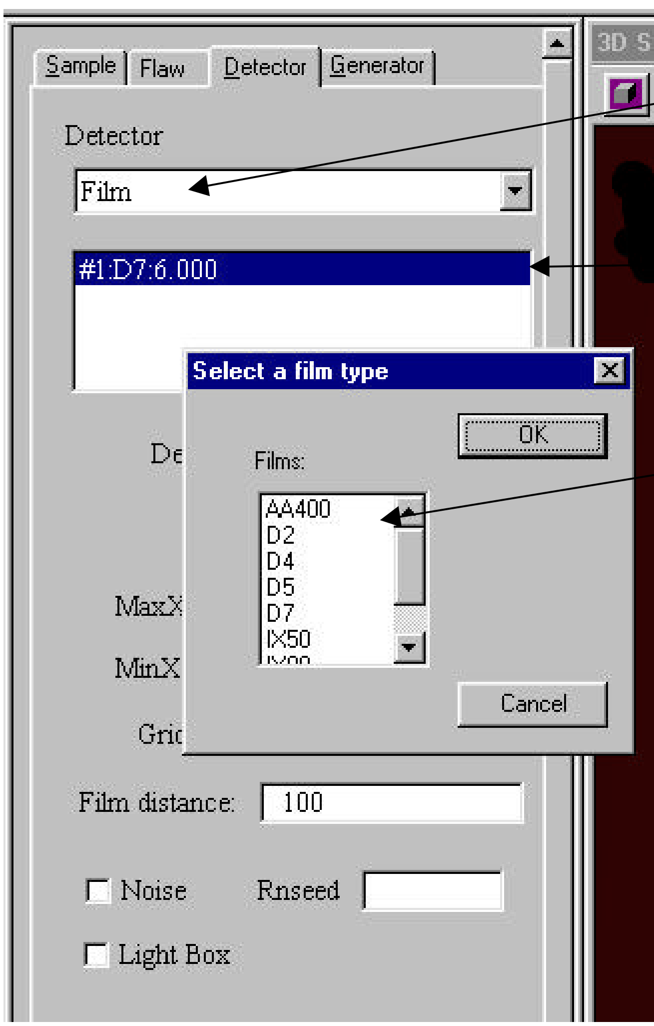


The thickness of the material penetrated by the radiation is shown as a function of color.

SELECTING THE FILM TYPE

A number of different films have been modeled in the XRSIM program. More information on the films included in the program is provided in Appendix B. It might seem that selecting the film should have been done when the film was resized, but there is a reason this step is placed here. The reason being is that prior to this step, anytime change in a parameter requires that the 2D thickness mapping process be run. Operations from this point on (changing the film type and adjusting the x-ray generator setting) do not require a new 2D-thickness map to be generated.

1. Make sure film is selected in the **Detector** dialog box on the **Detector** set-up window (future releases of the program will have the capability to model an inspection using and image intensifier and to model double loads of film. These features are not currently available.)
2. Select a new film type by clicking on the film type in the second dialog box on the window. This action will open a film selection window.
3. A new film type can be selected by highlighting the desired film in the list of film in the **Films** dialog box and click the **OK** button.



On the Detector set-up window, make sure that Film is selected in the **Detector** dialog box.

A film type will be show in this box. To change the film type, click on the shown film and a film selection window will opened.

Highlight a new film type and click on the **OK** button.

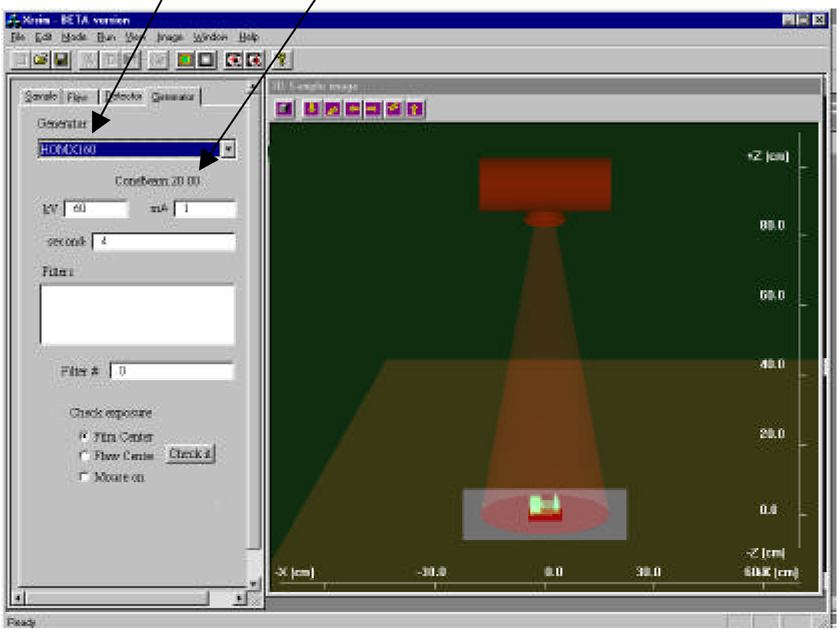
SELECTING AN X-RAY GENERATOR

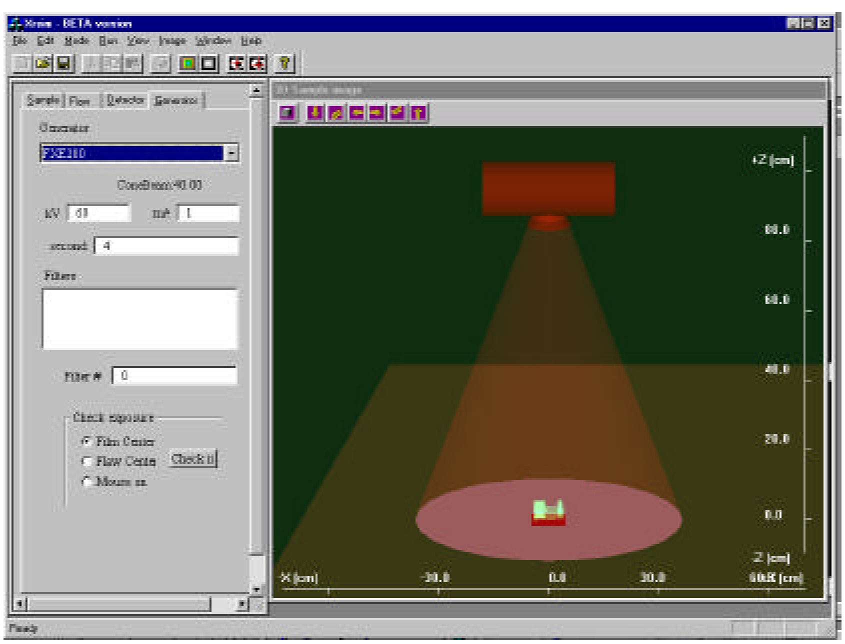
Once the film type has been selected, a generator must be selected and the generator setting adjusted. A number of x-ray generator systems have been characterized and are modeled in XRSIM. More information on these systems is provided in Appendix C.

1. Display the generator set-up window by clicking on the **Generator** tab.
2. Select the desired generator from the list provided in the **Generator** dialog box. You will notice that the x-ray cone beam is different for some of the generators. The angle of the x-ray tube's cone beam is displayed in the set-up window and shown in the 3D window.

Select a generator from the list provided in the **Generator** dialog box

The angle of the cone beam for the tube is shown





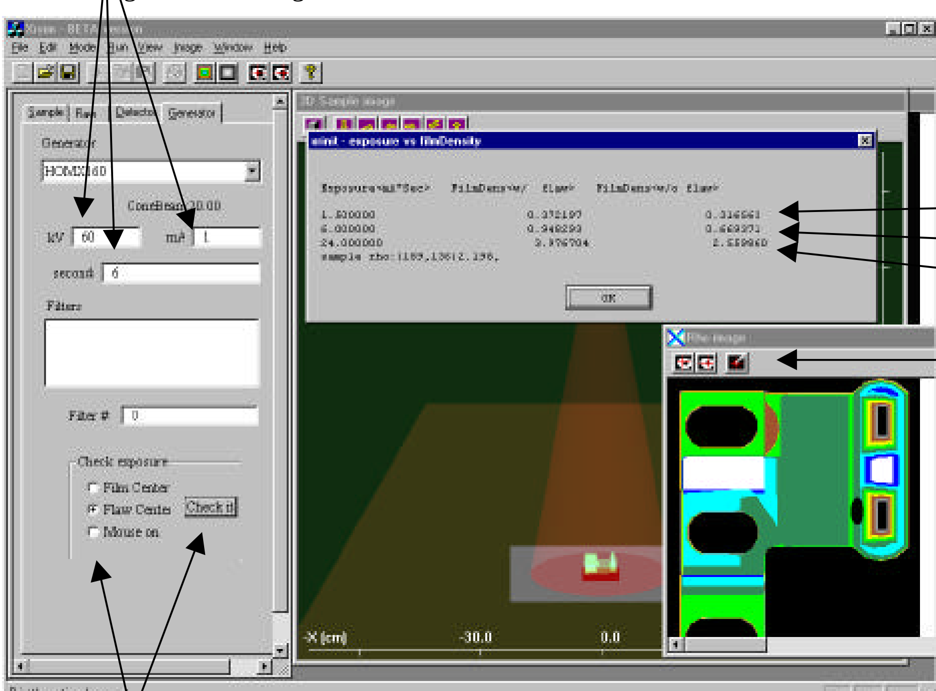
In the upper image, the tube has a 20 degree cone beam while the tube in the lower image has a 40 degree cone beam

ADJUSTING THE X-RAY GENERATOR SETTINGS AND CHECKING THE EXPOSURE

Like any x-ray generator system, there are three generator variables in XRSIM that must be set to achieve the desired radiographic image. These variables include the voltage, which controls the energy of the radiation; the amperage, which controls the amount of radiation produced in a set time; and the timer, which controls the length of time that the film is exposed to the radiation. Once the variables have been adjusted, a quick check of the film density can be made to determine if the exposure is correct. The density can be checked at the file center, at the flaw center (if a flaw has been included in the set-up), or at any point on the 2D thickness map.

1. Adjust the voltage (kV), amperage (mA), and exposure time (seconds) by typing a numerical value in the propre dialog box on the generator set-up window. **The enter-key must be pressed after a value is entered in order for the new value to take effect.**
2. Check one of the **Check exposure** options in the lower portion of **Generator** set-up window. A window will open and display the density values. The center row contains the densities for the current generator settings. The first row indicates what the densities would be if the exposure was decreased by a factor of four. The third row indicates what the densities would be if the exposure was increased by a factor of four. The exposure time is reported in mA-seconds since it is the product of these two variables that controls the exposure. When there is a flaw placed in the sample and the **Flaw Center** location is selected, the second column is the density at the center of the flaw and the third column is the density adjacent to the flaw. When the **Mouse On** location is selected, the density is displayed for any location where the mouse is clicked on the 2D-thickness map image. Hot buttons are also provided on the 2D-thickness map window for the three density check options.
3. Close the **Density Check** window by clicking on the **OK** button.

Enter numerical values in the **kV**, **mA**, and **second** dialog boxes to adjust the x-ray generator settings.



The check exposure window presents density values for
¼ exposure
current exposure
4x exposure.

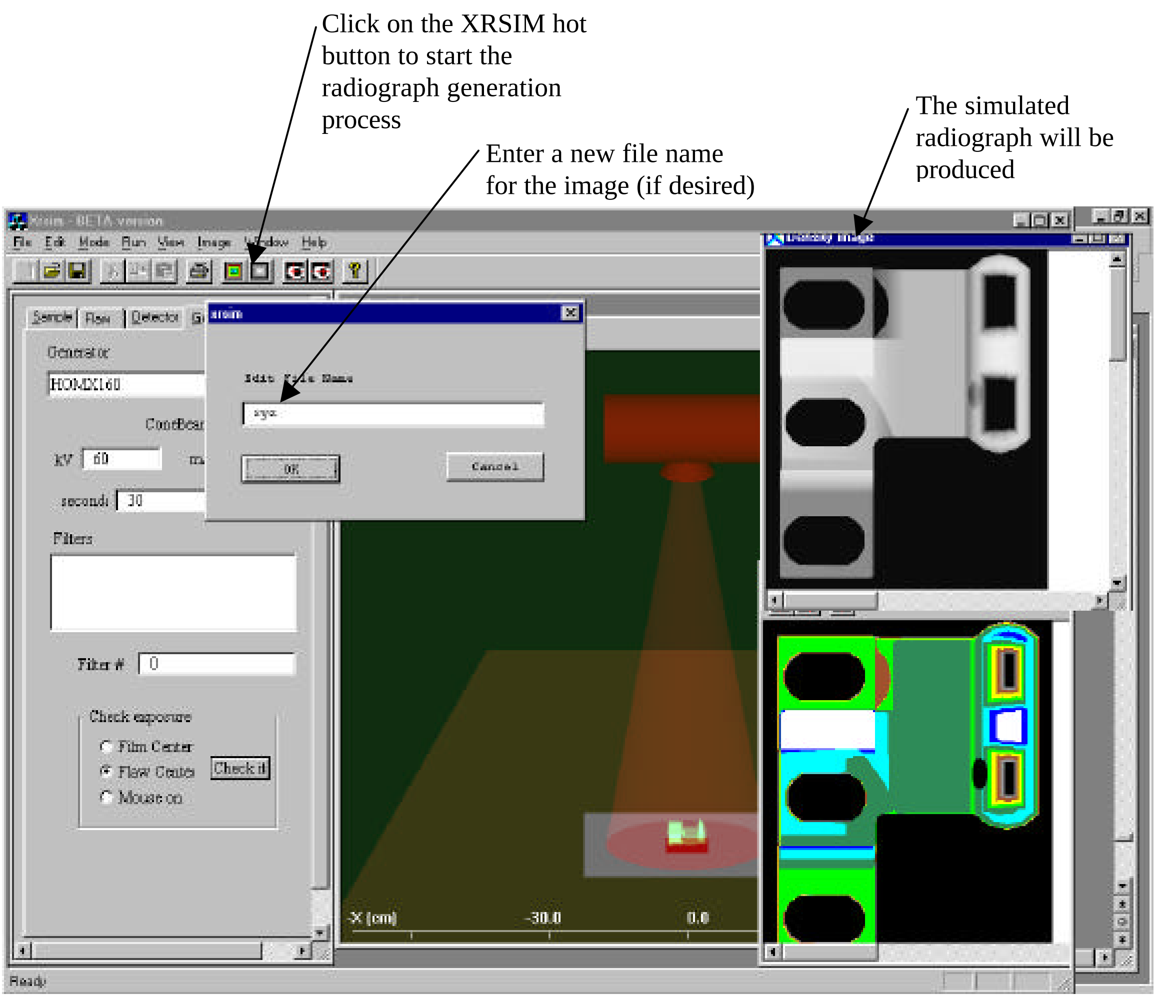
Hot buttons are provided for the three check exposure options

Select a check exposure option and click on **Check** it to perform a quick check of the density.

EXPOSING THE FILM TO PRODUCE THE SIMULATED RADIOGRAPH

Once the x-ray generator has been configured to yield the desired density, the simulated radiographic image can be produce. The film type and the x-ray generator setting can be changed and additional images can be quickly be produced by repeating the procedure on this page. A new 2D-thickness map does not need to be generated unless the size, position, or orientation of the sample flaw, or film is modified.

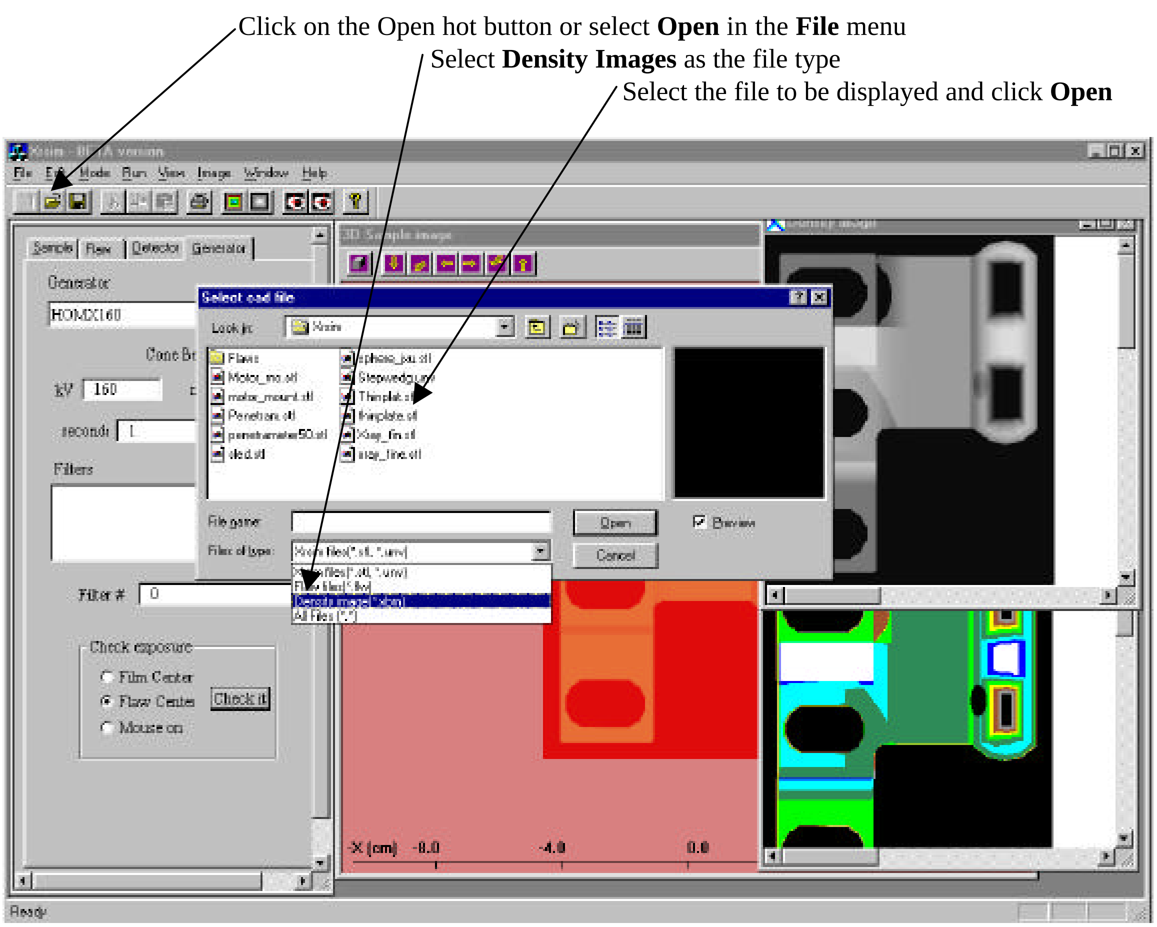
1. Run the process to produce the radiographic image by clicking on the **Run XRSIM** hot button or selecting **XRS** in the **Run** menu.
2. Edit the file name in the pop-up box to save the radiographic image and click on the **OK** button. The file will be automatically given an "xbm" extension. If the file name is not changed, the file will be overwritten the next time this procedure is preformed.



OPENING MULTIPLE RADIOGRAPHIC IMAGES

Multiple radiographic images can be open at the same time so that side-by-side comparisons of results can be made.

1. Click on the **Open** hot button or select **Open** in the **File** menu and the **File Open** window will appear.
2. Select **Density Images (*.xbm)** in the Files of type dialog box to display image files available to choose from.
3. Select a file to display and click the **Open** button. The image will be displayed.
4. Repeat the procedure to open additional images



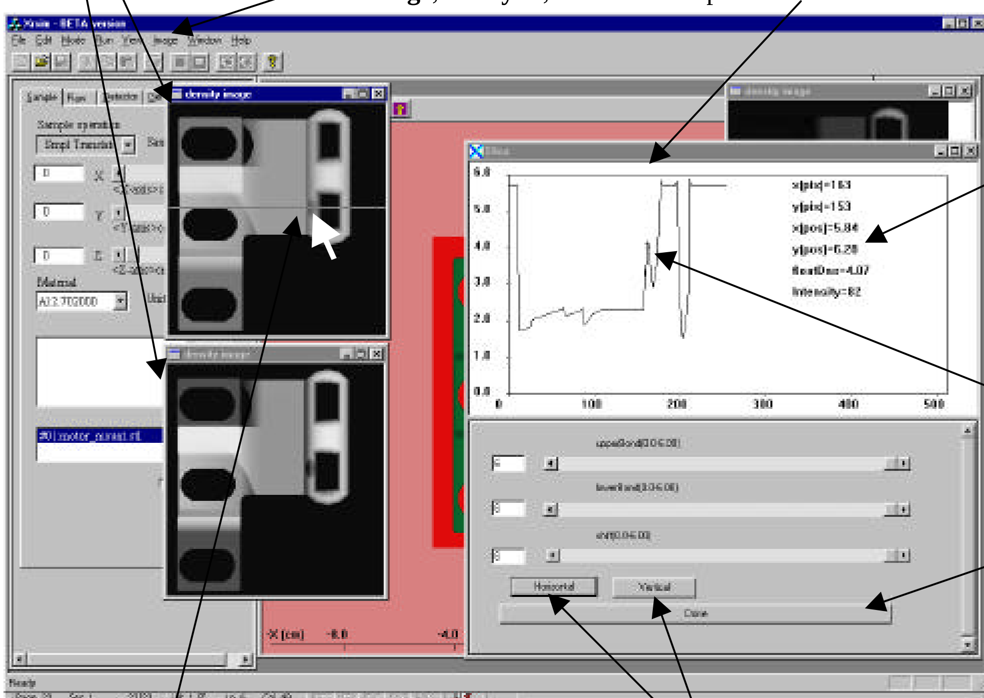
ANALYZING THE IMAGE DENSITY USING THE SLICE FEATURE

XRSIM has an image analysis feature that can be used to obtain quantitative density information from the radiographic image. This feature produces a plot of density versus position for any horizontal or vertical line across an image. The density at the point where the cursor arrow is positioned is provided in the digital readout.

1. Open one or more of the density images to be analyzed.
2. Select the **Image** pull-down menu, then **Analysis**, then **Slice.** The **Slice** analysis window will be displayed.
3. Click the **Horizontal** button in the slice window if a plot of densities along a horizontal line across the image is desired; or click on the **Vertical** button if a plot of densities along a vertical line across the image is desired.
4. Click and hold down the left mouse button on the image to be analyzed. A horizontal or vertical line, depending on the selection n step 3, will be displayed across the image. The densities along this line will be plotted in the **Slice** window. A small "x" will indicate the position of the cursor arrow in the image and the density and pixel location for this point will be provided.
5. Click on **Done** in the **Slice** window to close the window

Open one or more density image files and position as desired on the screen.

Select **Image**, **Analysis**, and **Slice** to open the **Slice** window



The density and position of the pixel at the tip of the cursor arrow is displayed.

The location on the plot is marked by a small "x."

Click on **Done** to close the window

Click and hold the mouse button down on the image to produce a slice line. The pixel density along this line and in the pixel that the cursor arrow points to is displayed in the **slice** window

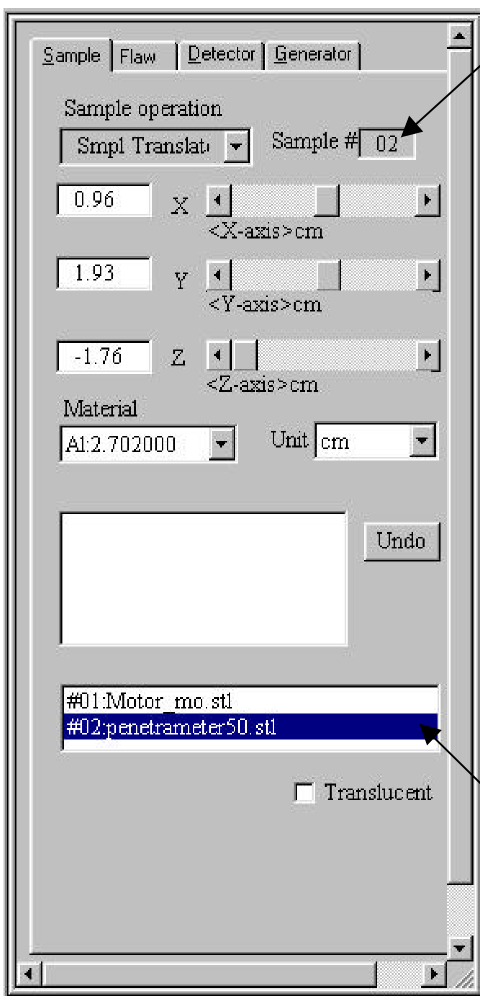
Click either **Horizontal** or **Vertical** to choose a slice direction (Horizontal was selected in this example)

SECTION 2- ADVANCED OPERATIONS

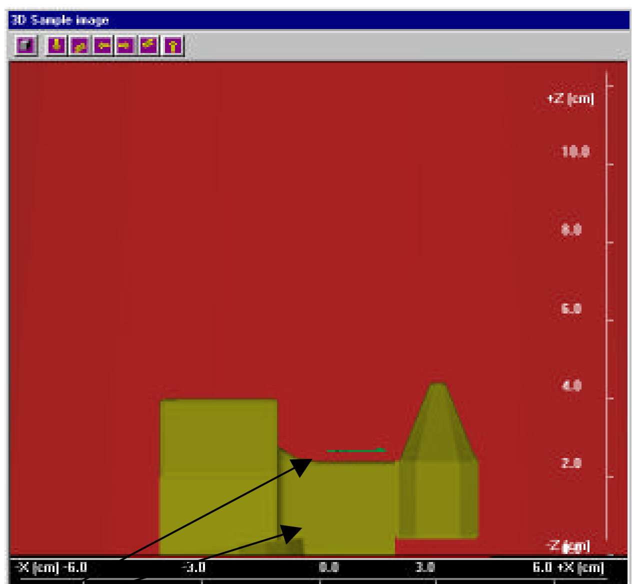
WORKING WITH MULTIPLE SAMPLES

The XRSIM program allows multiple sample CAD files to be opened so that inspections with multiple objects can be modeled. This feature makes it possible for image quality indicators to be placed on the part being radiographed. It also makes it possible to simulate the inspection of assembled or stacked components.

1. Opened the sample CAD files as explained in Section 1. The procedure is repeated for each new sample CAD file brought into the program. Once opened, the samples will be seen in the **3D Sample Image** window.
2. The names of the opened sample CAD files are shown in a dialog box in the lower portion of the **Sample** set-up window.
3. The file that is highlighted in the dialog box is the active sample and the number of the active sample is shown in the **Sample #** box near the top right corner of the window. The active sample can be moved, rotated, and scaled as explained in Section 1. The material for each of the open files must also be selected.



The number of the active sample number is indicated here.



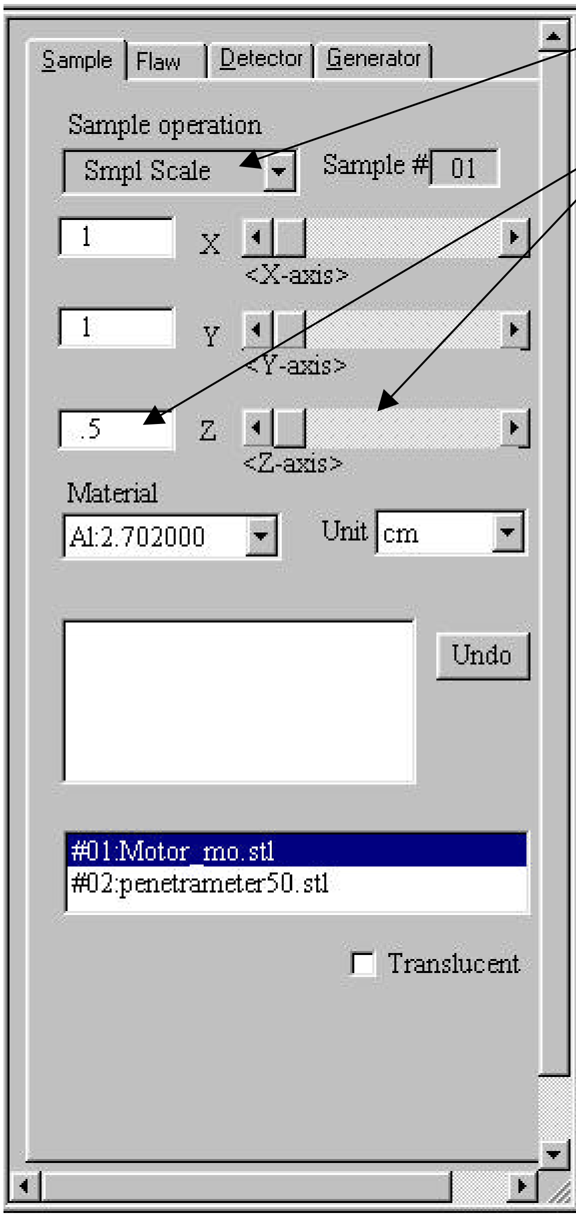
The opened samples appear in the 3D Sample Image window. Here a penetrameter has been placed on the part being inspected.

The sample CAD files that have been open are listed here. The highlighted file name is the active sample.

RESIZING THE SAMPLE

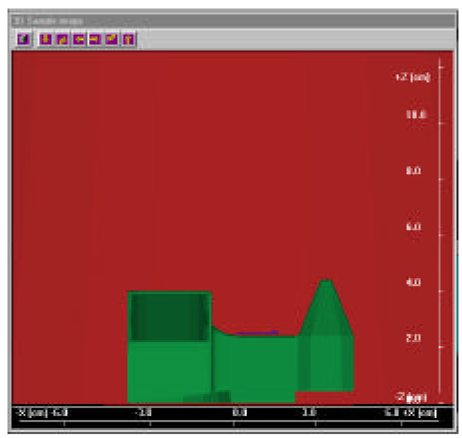
The samples CAD images can be modified to a limited degree in the program so that dimensional changes can be evaluated and a collection of generically shapes sample files can be modified for use in a large variety of inspection applications. For example, one pemetrameter CAD file can be scaled to represent nearly any penatrameter needed. Also, a single stepwedge CAD file can be modified to cover a large range of material thicknesses.

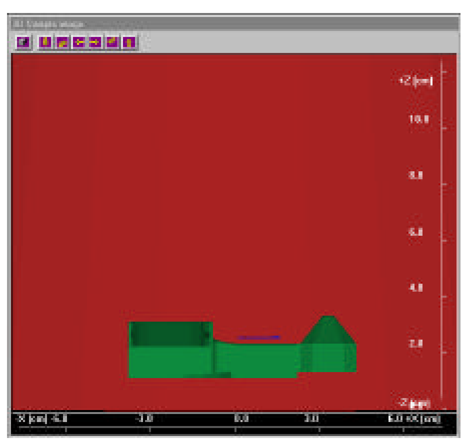
1. In the **Sample** set-up window, choose **Smpl Scale** in the **Sample operation** dialog box.
2. The sample can be scaled up or down by typing a scaling factor in the in the dialog box (remember that the change takes effect only when the enter key is depressed) or by using the slider bar or arrows to change the scaling factor. A dialog box and slider bar is provided for each of the three dimensions of the sample.



Choose **Smpl Scale** in the **Sample operation** box

Enter a value or use the slider bar to choose a scaling factor. The Z dimension has been scaled by a factor of 0.5 to change the sample from that show in the top image to that show in the lower image

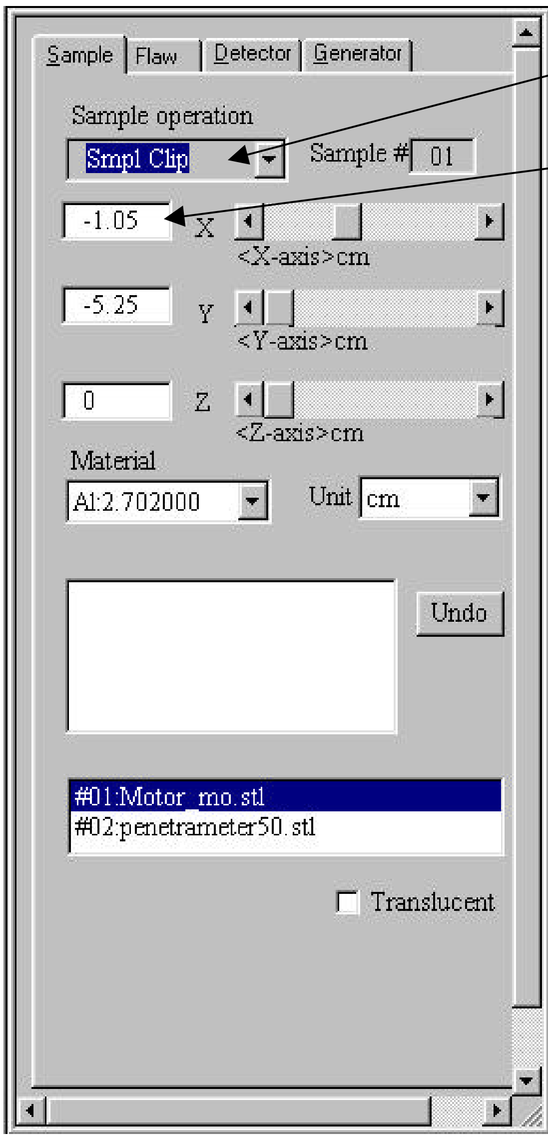




CLIPPING A PORTION OF THE SAMPLE

In addition to scaling, the sample can be modified by clipping portions of the sample. Using this feature, undesirable or unnecessary portions of the sample can be eliminated. The actual CAD file is not changed.

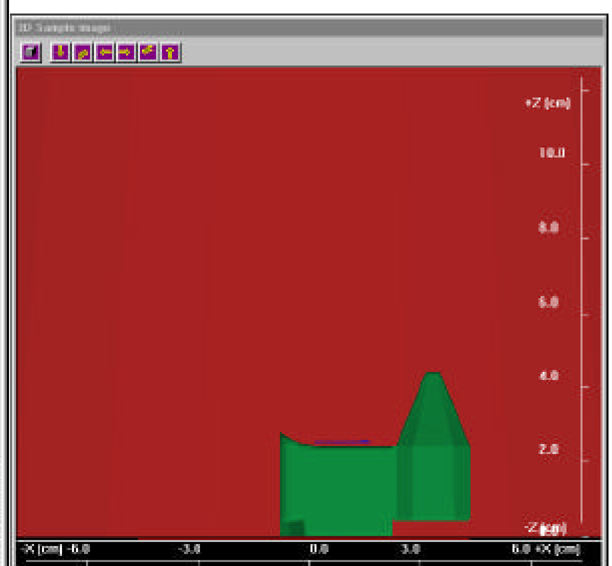
1. In the **Sample** set-up window, choose **Smpl Clip** in the **Sample operation** dialog box.
2. The sample can be clipped by typing a value in the in the dialog box (remember to depress the enter key) or by using the slider bar or arrows. A dialog box and slider bar is provided for each of the three dimensions of the sample. The value in the dialog boxes is the positions of one edge of the sample on the respective axis. The part will be clipped to the position on the axis that is entered in the dialog box.



Select **Smpl Clip** in the **Sample operation** dialog box

Enter a value or use the slider bar to clip the sample to a position on an axis

In this example, the left side of sample #1 has been clipped to the –1.05 position on the X-axis.

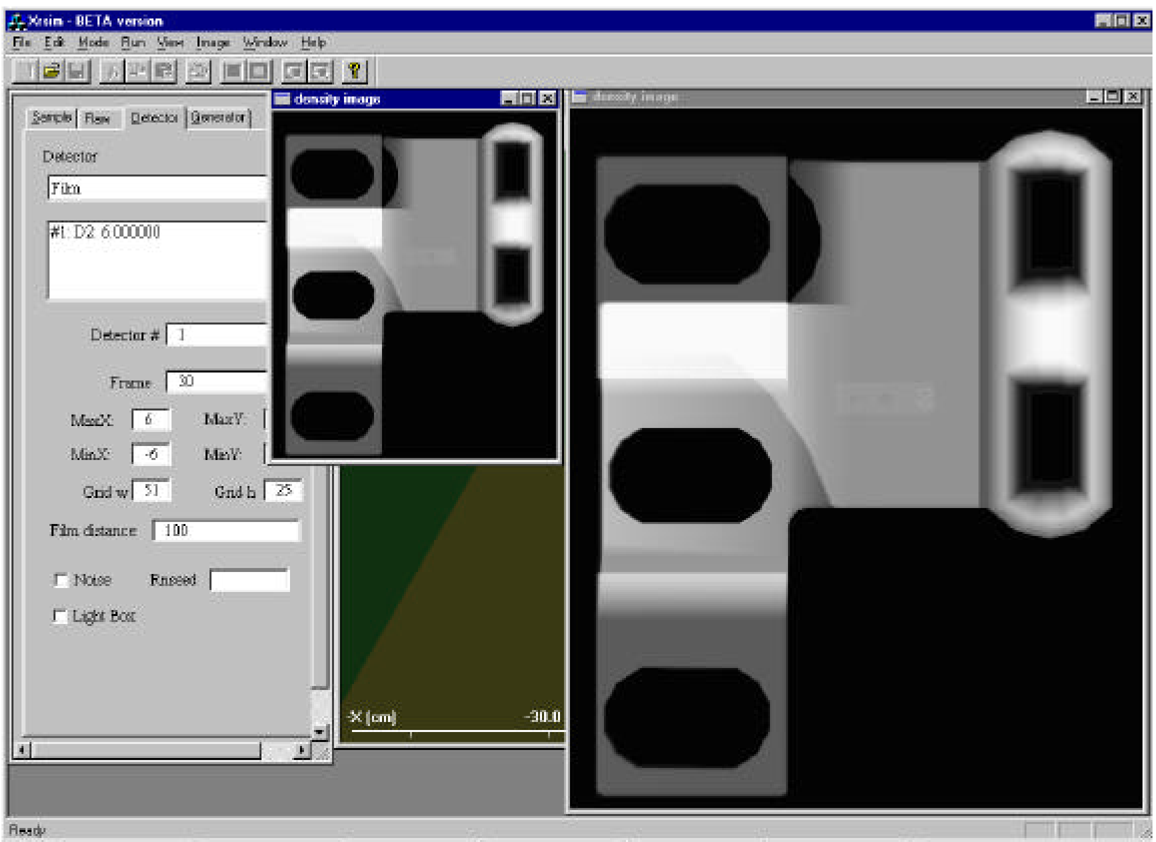


MODIFYING THE RESOLUTION OF THE IMAGE

The resolution of the simulated radiograph can be modified by changing the number of pixel used to display the image. In the default condition, the width of the image is set to 256 pixels and the height is scale to match the ration of the film width to height. In other words, if the film is square, the width of the simulated radiograph will be 256 pixels and the height will also be 256 pixels. If the film is twice as wide as it is high, the width of the radiograph will still be 256 pixels but the height will be 123 pixels. The size of the radiograph can be modified by changing either the width or height grid size and other dimension will automatically scale to match the height/width ratio of the film.

1. In the **Detector** setup window, enter the desired number of pixels in either the Grid w (width) or Grid h (height) dialog boxes. The default value for the width is 256 pixels so if an image twice the standard size is desired, 512 pixels should be entered in the Grid w dialog box.
2. Run the **Cad** program. Please note the processing time increases as the image size is increased.
3. Run **xrsim** program to produce the simulated radiograph.

The image on the left was produce using the default value for the grid size (256 pixels wide). Specifying an image width of 512 pixels produced the image on the right.



APPENDIX A

List of Specimen and Flaw Materials

XRSIM Identification	Density (grams/cm^3)	Description
Void	0.00129	Air filled void
Be	1.84800	Beryllium (pure)
Al	2.70200	Aluminum (pure)
Ti	4.54000	Titanium (pure)
Fe	7.87000	Iron (pure)
Ni	8.90000	Nickel (pure)
Cu	8.96000	Copper (pure)
Mo	10.22000	Molybdenum (pure)
Ag	10.5000	Silver (pure)
Pb	11.35000	Lead (pure)
W	19.29900	Tungsten (pure)
Air	0.00129	Air
Water	1.00000	Water (pure)
Quartz	2.64000	Quartz
Leather	1.64000	Leather
A2024	2.27000	Wrought Aluminum Alloy 2024 (Copper is the main alloying element)
A7075	2.81000	Wrought Aluminum Alloy 7075 (Zinc in the main alloying element)
A6061	2.70000	Wrought Aluminum Alloy 6061 (Magnesium and Silicon are the main alloying elements)
A356	2.29600	Cast Aluminum Alloy A356
Al2O3_b	2.60000	Aluminum Oxide (density 1)
Al2O3_c	2.00000	Aluminum Oxide (density 2)
Al2O3_d	1.60000	Aluminum Oxide (density 3)
Bone	1.65000	Human Bone (density 1)
Bone_a	1.45000	Human Bone (density 2)
Bone_b	1.25000	Human Bone (density 3)
Bone_c	1.15000	Human Bone (density 4)
SS304	7.56170	Stainless Steel Alloy 304
Sapphire	4.00000	Sapphire
MgZk60	1.83000	Forged Magnesium Alloy Zk60 (Zinc and Zirconium are the main alloying elements)
Mg_WE43	1.84000	Cast Magnesium Alloy WE43 (Yttrium is the maim alloying element)
Custom	User Defined	Using this setting, a density can be enter by the user

APPENDIX B

General Film Characteristics

Film	Producer	ASTM Class	Grain Size	Contrast	Speed	Common Applications
IX50	Fuji	1	Extremely-Fine	High	Slow	welds, aircraft, graphite epoxy composites
IX80	Fuji	1	Extremely-Fine	High	Medium	aircraft, welds, castings, high energy
D2	Agfa	Special	Extremely Fine	High	Slow	castings, welds, electronics, composites, highest quality
D4	Agfa	1	Extra-Fine	High	Medium	aircraft, medium castings and welds
D5	Agfa	1	Fine	High	Fast	multiple film techniques, thick castings and welds
D7	Agfa	2	Fine	High	Fast	high density, neutron radiography, thick castings
AA400	Kodak	2	Fine	High	Fast	castings, welds, heavy construction
M	Kodak	1	Ultra-Fine	High	Slow	aircraft, welds, castings, high energy

APPENDIX C

X-ray Generator Descriptions

Generator Identification	Maximum kV	Maximum Power Output (Watt)	Max mA[1]	Target Material and Angle	Spot Size (mm)	Window Material	Window Thickness (mm)	Cone Beam Angle
HOMX160	160	275	5	W 20^o	0.001 to 0.1	Al		20^o
FXE200	200	300	1.5	W 21^o	0.005 to 0.1	Be	0.5	40^o
IRT320	320	3200	30	W 70^o	3.0	Be	5.0	20^o
HF160	160	2400	15	W 45^o		Be		40

1 - The maximum mA values are limited by the maximum power (kV x mA) capability. As kV is increased, mA will decrease to stay within limits.

CREATING AN IMAGE USING XRSIM

The student will now create an image using the simulator. Keep this manual with you at your computer.

1. Open the simulation program by clicking on the Icon in the start up menu.

2. When the program opens you will see the four tabs, *sample, flaw, detector*, and *generator* in the left window, and the image of the x-ray tube and film in the right window. Page 5 will present a view and explain the tabs in more detail if you need.

3. The *sample* tab will be active. In the upper left corner of your screen left click on *file,* and open. When the window appears left click on the stepwedge and then open. The stepwedge will appear under the xray tube.

4. Change your view of the part by left clicking on the *top view arrow* (down arrow above and to the left of the x ray tube). You will now be viewing the part from above. You will now need to expand your film to make sure all the part is imaged. At a corner left click, hold, and drag the film until it is larger than your part.

5. You will notice that the part is not in the correct position. You will need to rotate it to locate it properly in relationship to the xray tube. Just under the sample tab you will see "sample operation", left click and choose "smpl rotate". In the X-axis place 90 and enter. When *inputting changes in the simulator your must complete your operation by pushing the enter key.* You will see the part in now in proper relationship with the tube and film. Change your view to a front view (arrow above the xray tube). You will see you need to move the part down in contact with the film. *Left click and drag* the stepwedge down. Give the part time to complete your move. On some systems the part will continue to move after you have released the left mouse button. With practice your will get on to this movement. Now is the time to select the material the stepwedge is made of. Under the x, y, and z windows you will see "material". Left click and you will see aluminum as the default, and a selection of materials to choose for the stepwedge. Lets change from aluminum to titanium. Click on titanium and change the stepwedge will have the properties of titanium. Lastly we will make the part translucent so as to see the location of the defect in the part. Move down and *left click* in the box next to translucent. You will notice the part changes colors and x y and z locations appear on the screen next to the x-ray tube.

6. Now that the part is set-up we will insert a defect into a step. *Left click on the flaw tab* and move your mouse to the upper left corner and *left click on file, and open*. In the cad select file *left click on sphere* and then open. A sphere will appear on the stepwedge. In the flaw operation window select "scale". You will place the defect in step eight so lets scale the flaw to represent a 10 percent loss of material. Step eight is 2.62 cm so a 10 percent loss would be 0.26 cm. In x box insert 0.26 and *press enter*. Do the same for y and z boxes. You will now see the defect has been reduced considerably. *Left click and drag the defect* until it is

centered from top to bottom in step eight. Change your view to the top view by *left clicking on the down arrow* above the x-ray tube. Note the location of the defect side to side. Just below the x y and z boxes there is a Material window. Left click and look over the materials that your defect can contain. When you are done return to air. Also you will see to the right the measurement units of the defect can be changed. The default is cm. left click you will see the system will measurer in other units. Choose inches and note what happens to the size of the defect. Return the defect dimensions to cm. and we will choose the film for our exposure.

7. Left click on the detector tab and note the window displaying film. Just below is a film D-2 listed. Left click and you will see a box open up in the right window just under the x ray tube. Scroll through the choices of films. Note there are a number of manufacturers represented, as well as a variety of speeds. Choose D-5 by left clicking on the film. Notice D-5 will appear in the window replacing D-2 was. Further down you will find a setting for *film distance*, notice the default is 100. This measurement is in centimeters. Change your view of the part by selecting *full view* above and to the left of the x-ray tube. In this view you will see the cone of radiation the x-ray tube, and the part. Change the source to film distance to 35 centimeters by removing 100 and replacing it with 35. *Remember* you must *push the enter button* to activate your change. Note the tube has moved considerably closer to the stepwedge. Left click on the top view and note the cone of radiation has become considerably smaller as the source to film distance is reduced. Return the distance to the default of 100 and we will make the generator settings.

8. *Left click on the Generator tab* to activate the generator settings. Left click on the generator and you will see there are four x-ray tubes modeled for the simulator. Select the FXE200. Notice the change in the cone of radiation from 20 degrees with the HOMX 160 to 40 degrees with this generator. Moving down the tab you will find Kilovoltage, milliamperage, and time settings for the simulator. Settings are not unlike a system you would use in industry. Maximum kilovoltage settings will be determined by the potential of the tube. Miliamp settings for the simulator will often be less than used in industry. Settings of 1 or 2 miliamps will be common on the simulator. Time settings will be measurerd in seconds. Make the following settings: 120 kv, 2 ma, and 12 seconds remembering to press enter after every setting change.

9. Now enter the settings you have inputted from each tab by moving to the top bar and left clicking on the square button with yellow and green boxes on it. It is located just above the generator tab. When you left click a window will open called xyz. Leave this as the defalt file and press enter. In a fiew seconds a RIO image will apear. This image is a thickness map of your part. Note that the part thicknesses are color coded. Also note defect shows up as a small black area indicating very little thickness in that area.

10. Moving to the left you will find at the bottom of the genorator tab a *Check Exposure* box. The simulator will allow you to check the density of your image without having to run the simulation program. Left click and choose flaw center. Now move to the bar above the exposure tab and select the button just to the left of the question mark. This will open the density check window. Notice there are three columns: time in miliamp seconds, density with (or at the flaw center) the flaw, and density without (density if the flaw were not there) the flaw. Below each are three time and resulting densitys listed. The *center time is what we have entered*. Above the time has been *reduced* by a *factor of four* and the resulting densities listed. Below the time has been *increased* by a *factor of four* and the resulting densities listed. *Use this feature to help determine settings when working on the simulator*. Checking this we see that 12 seconds gives us a density of 0.5. Using the "double the time double the density" rule change the time to 24 seconds press enter and check the resultant density. We see a density not of 1.01 which is as expected. Increase the miliamp setting to 3 and note that the message is given that you are outside of settings. The system will not let you increase the milimps above 2. Reduce the miliamp setting to 2 and increase the time to 48 seconds, this will yield a density of around 2.0.

11. Moving left to the square button with the grey boxes click to activate the radiographic image. Notice the edit file window opens. The file will default to xyz. To save this image you will need to change the name of the file to xy1 or give it the name of your choice. Left click ok and the simulator will begin it's calculations. When complete a density image window will appear showing the stepwedge and resulting densities.

12. Using the slice option review the densities. First you need to call up the file xy1. In the upper left hand corner go to file, and open. A window will appear. Go to file type and highlight density image, and then open. A list of images will appear, select your xy1 file, and open the density image window will now open in the upper left of your screen. On the upper bar highlight view, image and left click on slice a window will open. Near the botom there will be horozontal vertical and end bars. Select horozontal and move your curser up to the density window you have just opened. Left click and drag your mouse over the stepwedge. Notice you are presented with a view of the part, x y locations and x y pixel counts. Move the point of your mouse from step to step noting the density at the point of the mouse. Carefully move the point over the defect in the part and note the increase in density. Change the setting to vertical and repeat the density check. Close the density check by left clicking on done. Next close the window with the radiograph.

13. To review we will make changes in the defect, part, and film.

A. Moving back to the flaw tab go to the window and change the flaw material from air to lead (pb) and press enter. Left click on the xrsim button (you do not need to name these files as we will not save them) and note the change in density of the defect.
B. Leaving the flaw Pb. Change the material in the stepwedge from titanium to aluminum by choosing the material tab, selecting al 2.702000 and pressing enter. Left click on the xrsim button and note the change in density of the radiograph.
C. Changing the film to a slower one may help so we will sellect the detector tab and highlight the D-2 film and review the selection when the window opens. Relitieve to the other films this is one of the slowest, so first we need to change the time and kilovoltage settings. Go to the generator tab and make the following settings remembering to press enter after each

selection. 80 kv 1ma and 5 seconds. Left click on the check density and you will see it has dropped considerably. Left click on the xrsim button and produce an image.

D. Call up the density file and check density over the step. First select file on the top bar then open, and then change the file type to “density image”. Select the xyz file and open. On the top bar select image, select and slice. When the slice window opens select horozontal and move your mouse over the step noting the denssities of the steps. When you are done close the slice and density windows.
E. The recorded densities of step eleven was less than one so we should be able to change to a faster film and still image the top steps. Select detector, and left click on the D-2 film and move to the window at the right. Select D-4 and click ok. Check your density at the flaw center by left clicking on the button left of the question mark. This should give us a reasonable density of the stepwedge. Left click on the xrsim button and run the program. Note the change in density.
F. Lastly change back to the D-2 film and we will make a distance change. Once the film has been selected move down the window and change the distance from 100 centemeters to 60, press enter and try and run xrsim. You will note the system prompts you to run the cad program first. Run the cad and then run the simulation and you will note the resulting change in denssities.
G.