8. Solid Modeling
Solid Modeling

Overview

• Importing geometry is convenient, but sometimes you may need to create it in ANSYS. Some possible reasons:
  – You may need to build a parametric model — one defined in terms of variables for later use in design optimization or sensitivity studies.
  – The geometry may not be available in “importable” format.
  – The Connection product you need may not be available on your computer platform.

• ANSYS has an extensive set of geometry creation tools, which we will discuss in this chapter.
Solid Modeling

...Overview

- Topics covered:
  
  A. Definitions
  B. Top-Down Modeling
    - Primitives
    - Working Plane
    - Boolean Operations
  C. Workshop
  D. Bottom-Up Modeling
    - Keypoints
    - Coordinate Systems
    - Lines, Areas, Volumes
    - Operations
  E. Workshop
Solid Modeling Definitions

- **Solid Modeling** can be defined as the process of creating solid models.
- Let’s review some earlier definitions:
  - A *solid model* is defined by volumes, areas, lines, and keypoints.
  - Volumes are bounded by areas, areas by lines, and lines by keypoints.
  - Hierarchy of entities from low to high: keypoints $\ll$ lines $\ll$ areas $\ll$ volumes. You cannot delete an entity if a higher-order entity is attached to it.
- Also, a model with just areas and below, such as a shell or 2-D plane model, is still considered a solid model in ANSYS terminology.
Solid Modeling

...Definitions

• There are two approaches to creating a solid model:
  – Top-down
  – Bottom-up

• *Top-down modeling* starts with a definition of volumes (or areas), which are then combined in some fashion to create the final shape.

![Diagram showing top-down modeling process](image-url)
Solid Modeling

...Definitions

- **Bottom-up modeling** starts with keypoints, from which you “build up” lines, areas, etc.

- You may choose whichever approach best suits the shape of the model, and also freely **combine** both methods.

- We will now discuss each modeling approach in detail.
Solid Modeling

B. Top-Down Modeling

• Top-down modeling starts with a definition of volumes (or areas), which are then combined in some fashion to create the final shape.
  – The volumes or areas that you initially define are called primitives.
  – Primitives are located and oriented with the help of the working plane.
  – The combinations used to produce the final shape are called Boolean operations.
Primitives

- Primitives are predefined geometric shapes such as circles, polygons, and spheres.
- 2-D primitives include rectangles, circles, triangles, and other polygons.
Solid Modeling - Top-Down Modeling

...Primitives

- 3-D primitives include blocks, cylinders, prisms, spheres, and cones.
When you create a 2-D primitive, ANSYS defines an area, along with its underlying lines and keypoints.

When you create a 3-D primitive, ANSYS defines a volume, along with its underlying areas, lines and keypoints.
Solid Modeling - Top-Down Modeling

...Primitives

- You can create primitives by specifying their dimensions or by picking locations in the graphics window.
  - For example, to create a solid circle:
    - Preprocessor > Modeling > Create > Areas > Circle >

- By picking...
- Or enter values here...
Solid Modeling - Top-Down Modeling

...Primitives

- To create a block:
  - Preprocessor > -Modeling- Create > -Volumes- Block >

Pick the desired locations in graphics window...

...Or enter values here
Solid Modeling - Top-Down Modeling

**Working Plane**

- The “WP” in the prompts and in the picker stands for *Working Plane* — a movable, 2-D reference plane used to locate and orient primitives.
  - By default, the WP origin coincides with the global origin, but you can move it and/or rotate it to any desired position.
  - By displaying a grid, you can use the WP as a “drawing tablet.”
Solid Modeling - Top-Down Modeling

...Working Plane

• All working plane controls are in Utility Menu > WorkPlane.

• The WP Settings menu controls the following:
  – WP display - triad only (default), grid only, or both.
  – Snap - allows you to pick locations on the WP easily by “snapping” the cursor to the nearest grid point.
  – Grid spacing - the distance between grid lines.
  – Grid size - how much of the (infinite) working plane is displayed.
You can move the working plane to any desired position using the **Offset** and **Align** menus.

- Offset WP by Increments...
  - Use the push buttons (with increment set by slider).
  - Or type in the desired increments.
  - Or use dynamic mode (similar to pan-zoom-rotate).
Solid Modeling - Top-Down Modeling

...Working Plane

- Offset WP to >

This simply “translates” the WP, maintaining its current orientation, to the desired destination, which can be:

- Existing keypoint(s). Picking multiple keypoints moves WP to their average location.
- Existing node(s).
- Coordinate location(s).
- Global origin.
- Origin of the active coordinate system (discussed later).
Solid Modeling - Top-Down Modeling

...Working Plane

- Align WP with >

This reorients the WP.

- For example, Align WP with Keypoints prompts you to pick 3 keypoints - one at the origin, one to define the X-axis, and one to define the X-Y plane.

- To return the WP to its default position (at global origin, on global X-Y plane), click on Align WP with > Global Cartesian.
Boolean Operations

- **Boolean operations** are computations involving combinations of geometric entities. ANSYS Boolean operations include *add, subtract, intersect, divide, glue, and overlap*.

- The “input” to Boolean operations can be any geometric entity, ranging from simple primitives to complicated volumes imported from a CAD system.
Solid Modeling - Top-Down Modeling

...Boolean Operations

• All Boolean operations are available in the GUI under Preprocessor > -Modeling- Operate.

• By default, input entities of a Boolean operation are deleted after the operation.

• Deleted entity numbers become “free” (i.e., they will be assigned to a new entity created, starting with the lowest available number).
Solid Modeling - Top-Down Modeling

...Boolean Operations

- **Add**
  - Combines two or more entities into one.
Solid Modeling - Top-Down Modeling

...Boolean Operations

- **Glue**
  - Attaches two or more entities by creating a common boundary between them.
  - Useful when you want to maintain the distinction between entities (such as for different materials).
Solid Modeling - Top-Down Modeling

...Boolean Operations

- **Overlap**
  - Same as glue, except that the input entities overlap each other.
Solid Modeling - Top-Down Modeling

...Boolean Operations

- **Subtract**
  - Removes the overlapping portion of one or more entities from a set of “base” entities.
  - Useful for creating holes or trimming off portions of an entity.
Solid Modeling - Top-Down Modeling

...Boolean Operations

- **Divide**
  - Cuts an entity into two or more pieces that are still connected to each other by common boundaries.
  - The “cutting tool” may be the working plane, an area, a line, or even a volume.
  - Useful for “slicing and dicing” a complicated volume into simpler volumes for brick meshing.
Solid Modeling - Top-Down Modeling

...Boolean Operations

- **Intersect**
  - Keeps only the overlapping portion of two or more entities.
  - If there are more than two input entities, you have two choices: *common* intersection and *pairwise* intersection
    - *Common* intersection finds the common overlapping region among all input entities.
    - *Pairwise* intersection finds the overlapping region for each pair of entities and may produce more than one output entity.
Solid Modeling - Top-Down Modeling

...Boolean Operations

• **Partition**
  - Cuts two or more intersecting entities into multiple pieces that are still connected to each other by common boundaries.
  - Useful, for example, to find the intersection point of two lines and still retain all four line segments, as shown below. (An intersection operation would return the common keypoint and delete both lines.)

![Diagram of Partition](image)
Solid Modeling - Top-Down Modeling

...Boolean Operations

• Demo:
  – “Drill” a hole by subtracting a circle from a rectangle (or a cylinder from a block)
  – Create two overlapping entities, save db, and do the overlap operation. Now resume db and add the entities. Note the difference between the two operations. (Glue is similar to overlap.)
  – Interesting model:
    • block,-2,2, 0,2, -2,2
    • sphere,2.5,2.7
    • vinv,all ! intersection
C. Workshop

• Refer to your *Workshop Supplement* for instructions on:

  [W6. Pillow Block](W6_Pillow_Block)
D. Bottom-Up Modeling

- Bottom-up modeling begins with a definition of keypoints, from which other entities are “built up.”

- To build an L-shaped object, for example, you could start by defining the corner keypoints as shown below. You can then create the area by simply “connecting the dots” or by first defining lines and then defining the area by lines.
Solid Modeling - Bottom-Up Modeling

Keypoints

- To define keypoints:
  - Preprocessor > -Modeling- Create > Keypoints
  - Or use the K family of commands: K, KFILL, KNODE, etc.

- The only data needed to create a keypoint is the keypoint number and the coordinate location.
  - Keypoint number defaults to the next available number.
  - The coordinate location may be provided by simply picking locations on the working plane or by entering the X,Y,Z values.

How are the X,Y,Z values interpreted? It depends on the active coordinate system.
Active Coordinate System

- Defaults to global Cartesian.
- Use `CSYS` command (or Utility Menu > WorkPlane > Change Active CS to) to change it to
  - global Cartesian `[csys,0]`
  - global cylindrical `[csys,1]`
  - global spherical `[csys,2]`
  - working plane `[csys,4]`
  - or a user-defined local coordinate system `[csys, n]`

Each of these systems is explained next.
Solid Modeling - Bottom-Up Modeling

...Coordinate Systems

Global Coordinate System

- The global reference system for the model.
- May be Cartesian (system 0), cylindrical (1), or spherical (2).
  - For example, location (0,10,0) in global Cartesian is the same as (10,90,0) in global Cylindrical.
Local Coordinate System

- A user-defined system at a desired location, with ID number 11 or greater. The location may be:
  - At WP origin [CSWP]
  - At specified coordinates [LOCAL]
  - At existing keypoints [CSKP] or nodes [CS]
- May be Cartesian, cylindrical, or spherical.
- May be rotated about X, Y, Z axes.
Solid Modeling - Bottom-Up Modeling

...Coordinate Systems

Working Plane Coordinate System

• Attached to the working plane.
• Used mainly to locate and orient solid model primitives.
• You can also use the working plane to define keypoints by picking.
Solid Modeling - Bottom-Up Modeling

...Coordinate Systems

- You can define any number of coordinate systems, but only one may be active at any given time.
- Several geometry items are affected by the coordinate system [CSYS] that is active at the time they are defined:
  - Keypoint and node locations
  - Line curvature
  - Area curvature
  - Generation and “filling” of keypoints and nodes
  - Etc.
- The graphics window title shows the active system.
Solid Modeling - Bottom-Up Modeling

Lines

- There are many ways to create lines, as shown here.
- If you define areas or volumes, ANSYS will automatically generate any undefined lines, with the curvature determined by the active CS.
- Keypoints must be available in order to create lines.
Solid Modeling - Bottom-Up Modeling

Areas

• Creating areas using bottom-up method requires keypoints or lines to be already defined.

• If you define volumes, ANSYS will automatically generate any undefined areas and lines, with the curvature determined by the active CS.

Create >
-Areas- Arbitrary

Operate > Extrude

Through RPs +
Overlaid on Area +
By Lines +
By Skinning +
By Offset +
Solid Modeling - Bottom-Up Modeling

Volumes

- Creating volumes using bottom-up method requires keypoints or lines or areas to be already defined.

Create >
-Volumes- Arbitrary

Operate > Extrude

![Extrude/Sweep window with options for Extrusion]

Areas -
- Along Normal +
- By XYZ Offset +
- About Axis +
- Along Lines +

Lines -
- About Axis +
- Along Lines +

Keypoints -
- About Axis +
- Along Lines +
• Boolean operations are available for entities created by both top-down and bottom-up modeling approaches.

• Besides Booleans, many other operations are available:
  – Extrude
  – Scale
  – Move
  – Copy
  – Reflect
  – Merge
  – Fillet
Solid Modeling - Bottom-Up Modeling

...Operations

Extrude

- To quickly create volumes from existing areas (or areas from lines, and lines from keypoints).
- If the area is meshed, you can extrude the elements along with the areas.
- Four ways to extrude areas:
  - *Along normal* — creates volume by normal offset of areas \([\text{VOFFST}]\).
  - *By XYZ offset* — creates volume by a general x-y-z offset \([\text{VEXT}]\). Allows tapered extrusion.
  - *About axis* — creates volume by revolving areas about an axis (specified by two keypoints) \([\text{VROTAT}]\).
  - *Along lines* — creates volume by “dragging” areas along a line or a set of contiguous lines \([\text{VDRAG}]\).
Solid Modeling - Bottom-Up Modeling

...Operations

Scale

• Useful for conversion from one units system to another.
• Discussed in Chapter 4.
Solid Modeling - Bottom-Up Modeling

...Operations

Move

- To translate or rotate an entity by specifying DX,DY,DZ offsets.
  - DX,DY,DZ are interpreted in the active CS.
  - To translate an entity, make the active CS Cartesian.
  - To rotate an entity, make the active CS cylindrical or spherical.

- Another option is to transfer coordinates to a different system.
  - Transfer occurs from the active CS to a specified CS.
  - This operation is useful when you need to move and rotate an entity at the same time.
Copy

- To generate multiple copies of an entity.
- Specify the number of copies and the DX, DY, DZ offset for each copy. DX, DY, DZ are interpreted in the active CS.
- Useful to create multiple holes, ribs, protrusions, etc.
Solid Modeling - Bottom-Up Modeling

...Operations

Reflect

- To reflect entities about a plane.

- Specify the direction of reflection:
  - X for reflection about the YZ plane
  - Y for XZ plane
  - Z for XY plane

All directions are interpreted in the active CS, which must be a Cartesian system.

What is the direction of reflection in this case?
Solid Modeling - Bottom-Up Modeling

...Operations

Merge

- To attach two entities together by removing coincident keypoints.
  - Merging keypoints will automatically merge coincident higher-order entities, if any.
- Usually required after a reflect, copy, or other operation that causes coincident entities.
Solid Modeling - Bottom-Up Modeling

...Operations

Fillet

- Line fillet requires two intersecting lines with a common keypoint at the intersection.
  - If the common keypoint does not exist, do a *partition* operation first.
  - ANSYS does not update the underlying area (if any), so you need to either add or subtract the fillet region.

- Area filleting is similar.
Solid Modeling - Bottom-Up Modeling

E. Workshop

• Refer to your *Workshop Supplement* for instructions on:

  W7. Connecting Rod