AutoCAD AME

solid modeling for mechanical design

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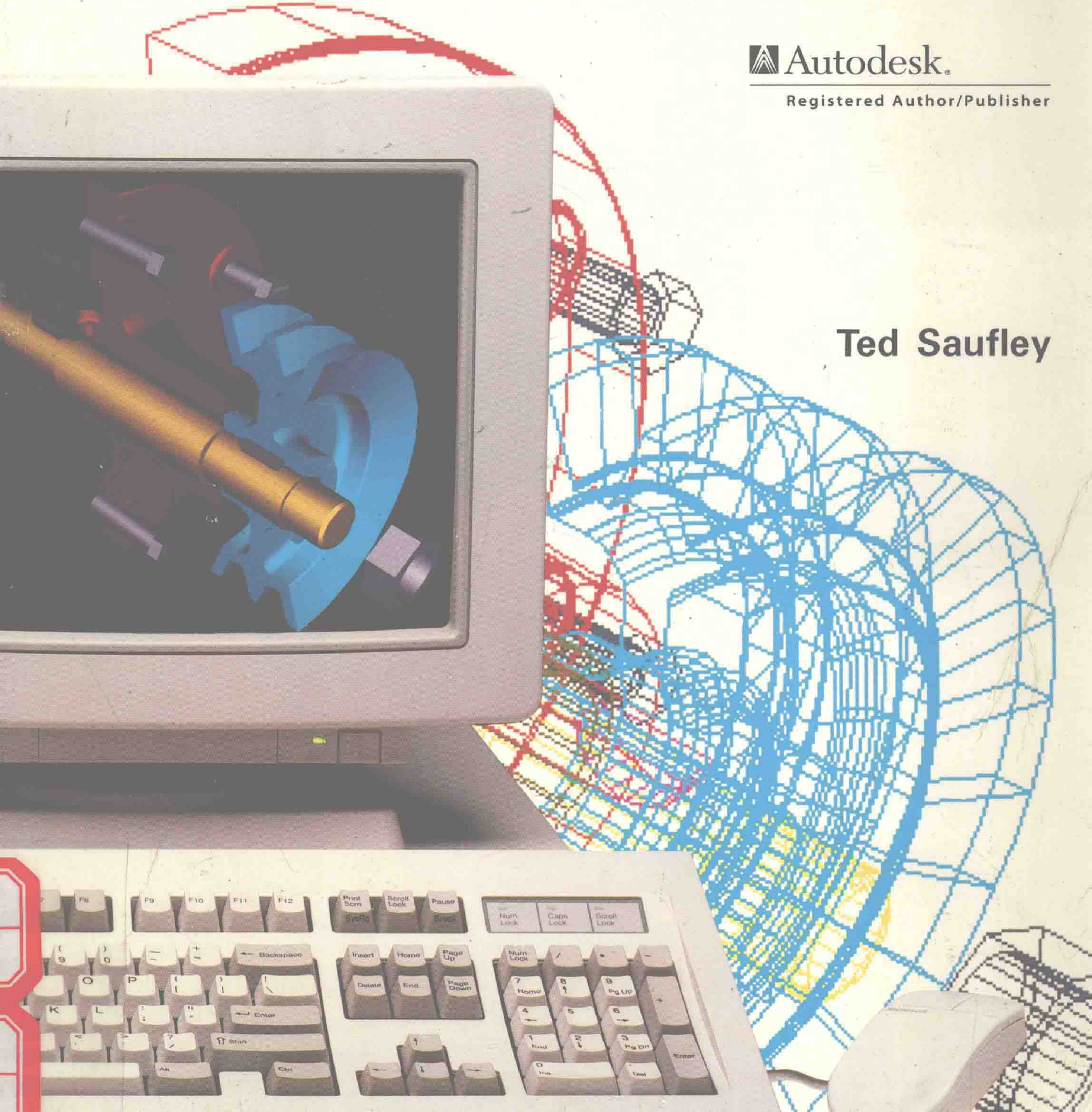
Ted Saufley



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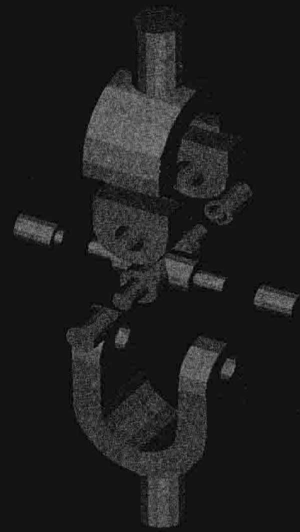

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Introduction

AutoCAD AME–solid modeling for mechanical design is a text and workbook combination that provides complete instruction in mastering AutoCAD® AME™ commands and solid modeling techniques. Typical applications of AutoCAD AME are presented with basic and easy-to-understand concepts and instructions. The topics are covered in an easy-to-understand sequence, and progress in a way that allows the learner to become comfortable with the commands as their knowledge builds from one chapter to the next. In addition, **AutoCAD AME–solid modeling for mechanical design** offers the following features:

- Step-by-step use of AutoCAD AME commands.
- In-depth explanations of how and why the commands function.
- Illustration to reinforce concepts.
- Step-by-step tutorials for command sequence guidance.
- Professional tips on how to use AutoCAD AME effectively and efficiently.
- Exercises involving tasks that reinforce the topics just covered.
- Chapter tests for reviewing commands and key AutoCAD AME concepts.
- Chapter problems to supplement each chapter.

Objectives

While the benefits of three-dimensional computer-aided solid modeling technology have long been known by the mechanical engineering CAD user community, solid modeling software has historically been prohibitively expensive and burdened with clumsy, non-intuitive user interfaces. As a result, its high cost and complexities have been too restrictive for the vast majority of users. But with the release in October 1990 of the Advanced Modeling Extension™ (AME) by Autodesk®, Inc., the advantages of solid modeling have become both affordable and easy-to-use for even the most casual AutoCAD user.

It is the goal of **AutoCAD AME–solid modeling for mechanical design** to provide a step-by-step approach in mastering AME commands. As the title of this text implies, the topics covered are designed primarily to address the needs of mechanical engineers, designers, and drafters. However, the solid modeling concepts presented are applicable to a variety of professional disciplines including civil and structural engineering, architecture, and facilities management. Each topic is presented in a logical sequence which permits the user to progress from the most basic 3D viewing and modeling commands to the more advanced editing and analysis functions.

Methodology

Historically, mechanical design engineers have generated 2D design layouts on the drafting board (in recent years, with CAD tools), and then relied on department draftpersons to produce the finished drawings. The detail drawing is then used to drive most, if not all, downstream operations. As the design is refined, the drawing is subjected to numerous revisions. For every drawing revision, updated prints are required and usually at least one copy of each updated print must then be distributed to every person involved with the project. Prints must also be made and distributed to outside vendors who are involved in the fabrication of the parts. Unfortunately, it is often likely that an updated print will not get to a vendor. This usually results in a large number of incorrect parts being produced at a staggering cost to the organization. The seemingly never-ending cycle of revise-print-distribute is very unproductive and extremely costly.

However, the design methodology employed in a computer-integrated manufacturing (CIM) environment is in stark contrast to the traditional design methodology long employed by manufacturing organizations. With 3D modeling techniques, it is the 3D model that drives the process and not the 2D drawing. Indeed, many engineering firms are producing entire products with no drawings at all. When, and if, a detail drawing is required, it is generated at the end of the design cycle and not at the beginning. In these instances, the drawing is used for documentation purposes only. Many computer-integrated organizations have found this design methodology to be more logical and cost-efficient. For such companies, a typical design sequence is outlined below:

1. Design and model the 3D mechanical part.
2. Edit the model to add features or correct errors in the part geometry.
3. Analyze the model to ensure compliance with physical and functional specifications. If the analysis results indicate some design modification is required, edit the model and perform the analysis once again.
4. Transfer the model file to manufacturing via network, modem, or floppy disk (often called "sneaker-net") to produce a prototype part.
5. If the actual part meets all specifications, then a detailed drawing of the part is produced for documentation purposes.

Thus, the order of subject material covered by **AutoCAD AME–solid modeling for mechanical design** closely parallels the more modern design methodology and is presented in the following sequence:

- Chapter 1–Introduction to Solid Modeling
- Chapter 2–Working in 3D Space
- Chapter 3–Modeling with Solid Primitives
- Chapter 4–Extrusions, Revolutions, and Region Modeling
- Chapter 5–Editing and Verifying the Model
- Chapter 6–Analyzing the Model
- Chapter 7–Detailing the Model
- Appendices and useful reference tables are found at the end of the text.

Introducing the AME commands

Like AutoCAD, each of the AME functions may be entered from the keyboard and, unless otherwise specified, each AME command and its related prompts is presented in this text as if it were typed in at the keyboard. This convention allows the reader to see the full command name and the syntax for the command-related prompts, messages, and options.

Commands, options, and values the user must enter are given in bold text as shown in the following example. Pressing the ENTER (RETURN) key is indicated with the ENTER symbol (↵).

Command: **VPOINT** ↵
Rotate/⟨View point⟩ ⟨0.000,0.000,1.000⟩: **1,–1,1** ↵

General input such as picking a point or selecting an object is presented in italics.

Command: **PLAN** ↵
⟨Current UCS⟩/Ucs/World: *(select an option or press ENTER to accept the default)*

Because AME offers the same easy-to-use interface as AutoCAD, the AME commands may also be accessed from the pull-down or screen menus, or from the AME tablet menu overlay. Since the aim of **AutoCAD AME–solid modeling for mechanical design** is to enable users to become proficient in as short a time as possible, readers are encouraged to invoke AME functions in whatever manner they find most convenient. To address this, alternative command-entry forms are also presented in the text.

NOTE

As a command-entry alternative, most of the AME functions may also be invoked with a shortened command alias such as: BOX for SOLBOX or CYL for SOLCYL. A complete listing of the AME command aliases appears in the appendices of this text.

Prerequisites

AutoCAD AME–solid modeling for mechanical design has been written for the user or student who already possesses a good working knowledge of AutoCAD. While prior experience with AutoCAD 3D drawing and viewing commands is helpful, it is by no means a necessary requirement.

Text design

Although **AutoCAD AME–solid modeling for mechanical design** may be employed as a stand-alone instructional guide, it can also be utilized as a companion text to **AutoCAD and its Applications** (Shumaker/Madsen, Goodheart-Willcox Company, Inc.). Because **AutoCAD AME–solid modeling for mechanical design** follows the same format as **AutoCAD and its Applications**, it can serve as an excellent training tool both in and out of the classroom environment.

The structure of **AutoCAD AME–solid modeling for mechanical design** lends itself to the development of a course devoted entirely to AME training. The major AME concepts that are related and build on each other are grouped together under numbered topics. The topics of each chapter include text material, and many include tutorials and exercises that are designed to provide the student with hands-on experience using the AME commands. The tutorials and exercises that accompany the topics introduce the commands necessary for mastery of AME. The tutorials are step-by-step instructions on how to solve AME-related problems. The exercises are AME-related problems that are associated with the topic(s) that were just covered in the text.

At the end of each chapter is a written test that may be used to evaluate the understanding of the chapter content. Also at the end of each chapter, "real-world" mechanical parts are presented as objects to be modeled with the methods discussed in the preceding text. The written test and modeling problems at the end of each chapter, reinforce subject material and help evaluate the progress of understanding the AME principles.

In addition to the previously mentioned features, there are a variety of notices throughout the text.

- **Professional Tips**–Notice of ideas and suggestions that are aimed at increasing productivity of the use of AME commands and techniques.
- **Notes**–Notice of important aspects of a command or activity that are being discussed.
- **Cautions**–Notice of potential problems that may occur if instructions or commands are used incorrectly, or if an action by the computer user could cause damage to files, directories, or disks. If there is any question about a particular caution, always consult an instructor or supervisor.

ABOUT THE AUTHOR

Ted Saufley has been involved with mechanical computer-aided engineering (MCAE) for over a decade; as a user, software developer, consultant, and educator. He currently teaches AutoCAD at Clackamas Community College in Oregon City, OR. This educational institution is an Authorized Training Center for AutoCAD® (ATC®).

NOTE

This text is designed as a complete AME teaching tool. The author presents a typical point of view. Users may find alternate and possibly better techniques for using AME. The author and publisher accept no responsibility for any loss or damage resulting from the contents of information presented in this text. This text contains the most complete and accurate information that could be obtained from various authoritative sources at the time of production. The publisher cannot assume responsibility for any changes, errors, or omissions.

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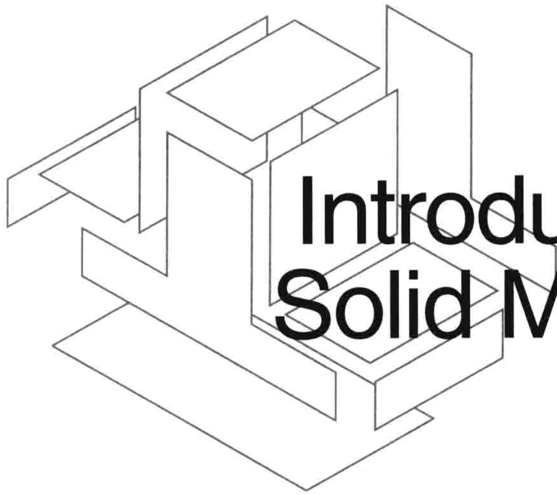
TRADEMARKS

Contents

Chapter 1



Introduction to Solid Modeling

Learning objectives

After you have completed this chapter, you will be able to:

- ☐ Identify the various geometric primitives used in solid models.
- ☐ List the advantages of solid modeling techniques over traditional three-dimensional wire-frame and surface models.
- ☐ Describe the results of Boolean operations upon solid primitives.
- ☐ Explain the two basic approaches to solid modeling (CSG and B-rep models).
- ☐ Load the Advanced Modeling Extension (AME) program and navigate its menu structure.
- ☐ Recognize the importance of precise coordinate entry.

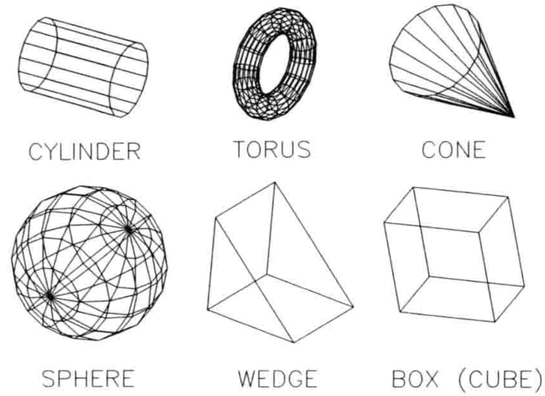
In computer-aided engineering, *solid modeling* is the process where three-dimensional (3D) geometry is constructed by adding, subtracting, and/or intersecting *solid primitives* together. Solid modeling may also be accomplished by extruding (adding height or depth) or sweeping (revolving about an axis) with two-dimensional (2D) geometric profiles (contours) to achieve three-dimensional solid objects.

TOPIC 1-1

SOLID PRIMITIVES

Solid primitives are the building blocks that comprise a solid model and are the most basic solid shapes you can create. Solid primitives include the rectangular box (or cube), cone, cylinder, sphere, torus (donut), and wedge as illustrated in Figure 1-1.

Figure 1-1. Solid primitives are the basic building blocks of solid modeling.

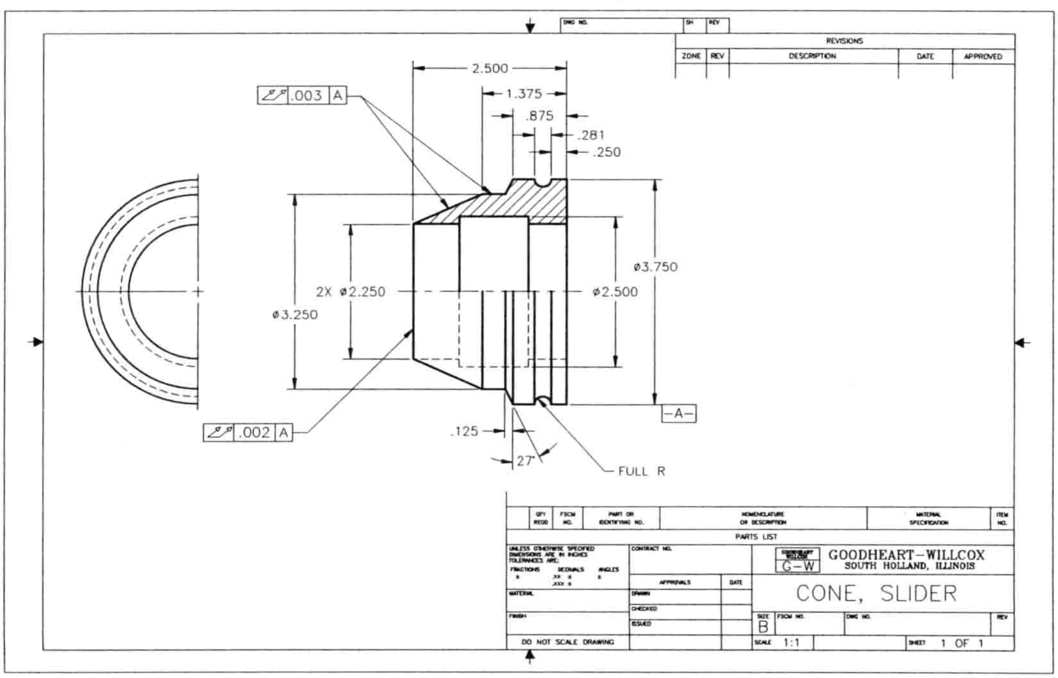


SOLID PRIMITIVES

Advantages over wireframe and surface modeling

Today most of the commercially available CAD programs offer a form of 3D geometric construction called *wireframe modeling*. In wireframe modeling, all edges of an object are shown as lines. Arc, circle, and spline entities are used to define curved features. The resulting model assumes the appearance of a frame constructed out of wire–hence the term "wireframe". The type of CAD files, 2D detail drawings, that you are already familiar with may also be classified as wireframe models. Such a 2D wireframe model is illustrated with the orthographic representation of the SLIDER CONE in Figure 1-2.

Figure 1-2. Typical mechanical detail drawing (SLIDER CONE). Conventional orthographic drawings such as this are 2D wireframe representations.



SLIDER CONE

In many cases, wireframe models are adequate to describe simple 3D constructions. Unfortunately, all of the lines that define the edges and surfaces of the model are clearly visible. These features are ones that would normally be hidden. Consequently, features and edges appearing at a given depth or at the rear of the model show right through to the foreground. This makes interpretation of the image difficult and ambiguous. Although many commercial wireframe modeling packages employ a software algorithm that performs "automatic hidden-line removal," they are often very compute-intensive and do not always perform as expected. Compare the 3D wireframe representation of the SLIDER CONE in Figure 1-3 with the detail drawing of the same object. While the geometry of the 3D model is identical to that of the 2D detail drawing, the lack of hidden lines makes the wireframe model more difficult to visually interpret. Another serious limitation of wireframe models exists in terms of their description within the CAD database. The database contains only line, vertex, and curve information. Since there is no data regarding the space between the edges of the object, surface intersections and sectional views are difficult to define.

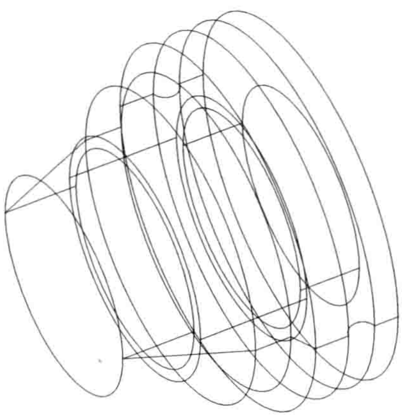
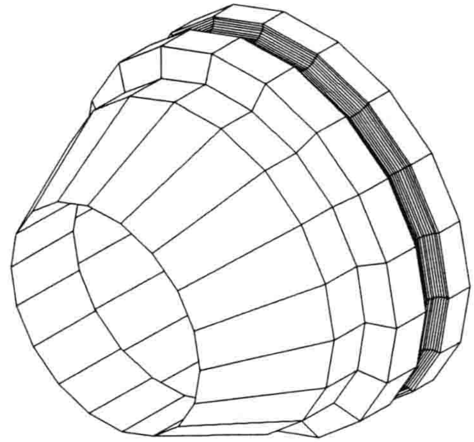

SLIDER CONE
(3D Wireframe)

Figure 1-3. 3D wireframe representation of the SLIDER CONE. Although somewhat difficult to visually interpret, the wireframe model is geometrically exact.

An improvement over the wireframe method of 3D modeling is the use of *surface modeling* techniques. Figure 1-4 is an example of a surface model of the SLIDER CONE. Not only do surface models contain information about the profile edges of an object, but they also contain information about the space between those edges. Therefore, it becomes possible to determine points along surface intersections. In AutoCAD, *polygonal meshes* comprised of many small planar faces are used to represent the surfaces of a wireframe model. The density of the mesh may be defined by the user. Such models are called *polyhedral* or *tessellated* models. While flat, planar features can usually be surfaced quite easily, curved features present more of a challenge. In both prototype and production manufacturing, surface modeling is often used by *numerical control (NC)* programmers to define the drive and check surfaces necessary to describe machine tool paths. Once a model is completely surfaced, it can often be shaded to give the appearance of a solid object. One drawback is that there is often ambiguity in the definition of one or more surfaces. This ambiguity pertains to which side is to appear solid. Essentially, a surface model may be thought of as just a shell that corresponds to the shape of the 3D wireframe object being modeled.

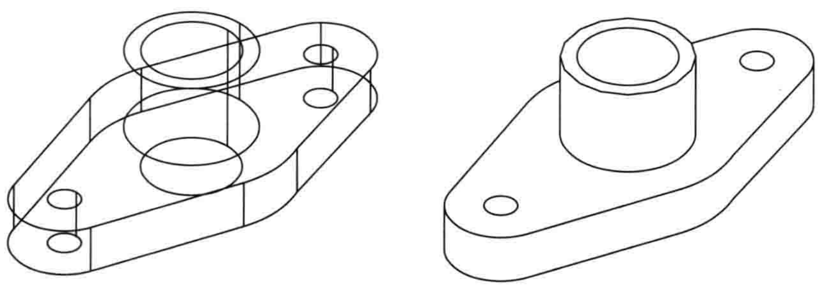
Figure 1-4. The SLIDER CONE modeled using surface meshes. In this example, a 2D profile of the SLIDER CONE is revolved about the part axis using a surface of revolution. Surfaces at the rear have been hidden for clarity.



SLIDER CONE
(Hidden Surfaces)

With the solid modeling approach to 3D modeling, there is very little risk of misinterpretation. Since all objects are displayed as solid to the viewer, edges and features that are normally hidden from view *are indeed hidden*. Compare the wireframe model of the GLAND with its solid model counterpart in Figure 1-5. For CAD workstations equipped with sophisticated

Figure 1-5. A visual comparison between the 3D wireframe representation of a GLAND (left) and the solid model of the same part (right). Although each model's database contains exactly the same geometric information regarding features and vertices, only the solid model database contains mass and volumetric data.



GLAND

graphics sub-systems, the judicious use of color, lighting, and textures can produce strikingly realistic images. These images may be printed on a variety of output devices. Some of these devices, particularly the thermal wax and the dye sublimation printers, can produce very realistic representations of the images. Even modest subsystems are able to create striking displays. The illustrations in Figures 1-6A through 6I were rendered using a VGA display resolution of 1024 × 768 with 256 colors. This screen resolution is quite common among AutoCAD users, and it is very affordable. Unlike wireframe and surface models that contain no material or volumetric data, detailed physical properties analysis can be performed on the solid model.

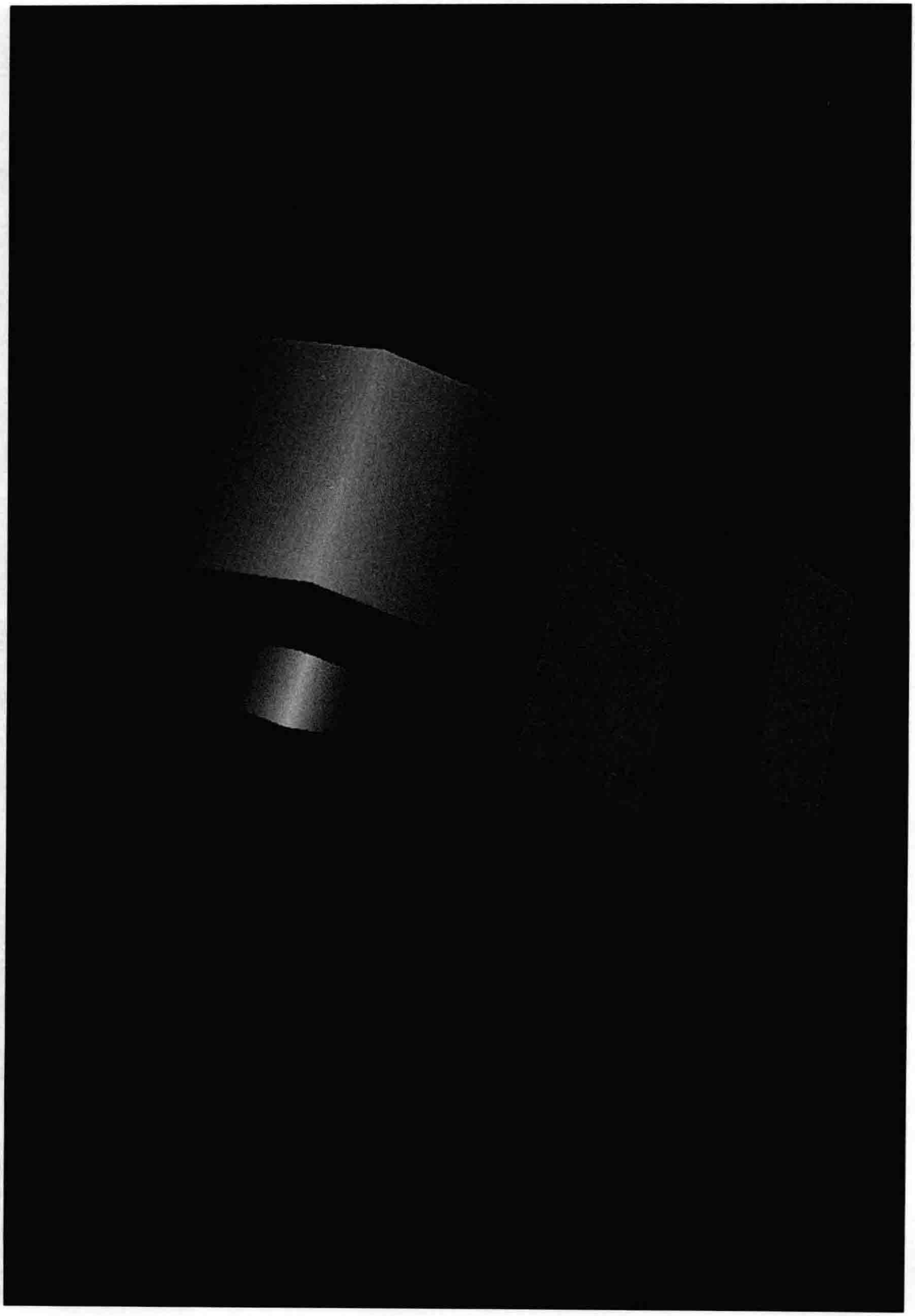


Figure 1-6A. The BEARING BRACKET from Chapter 2.

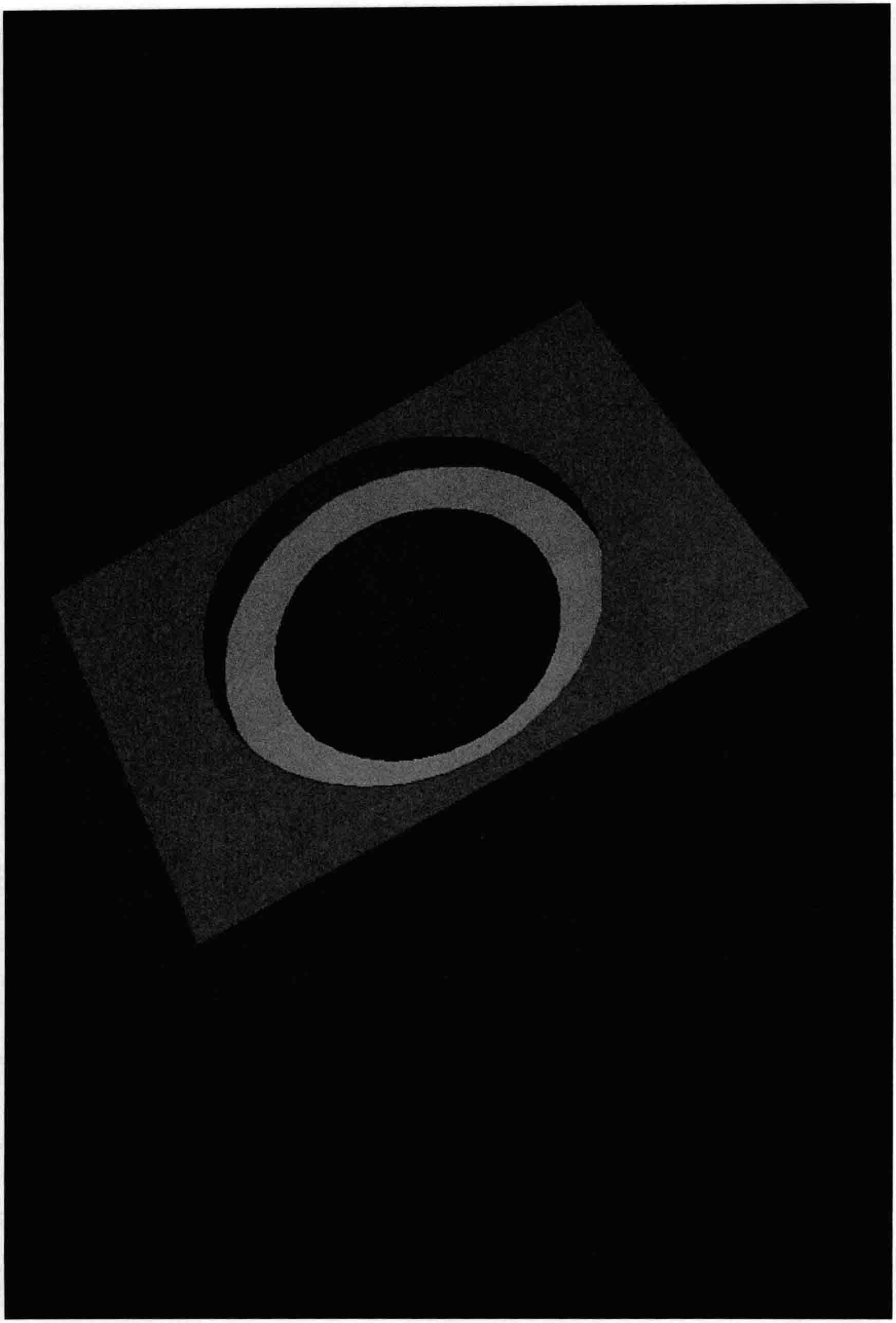


Figure 1-6B. The SLANTED BLOCK from Chapter 3.