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SDC
SOLENOIDAL DETECTOR NOTES

DESIGN OF A TRACKING SYSTEM FOR A SOLENOIDAL DETECTOR

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DESIGN OF A TRACKING SYSTEM FOR A SOLENOIDAL DETECTOR*

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Abstract

The design of an integrated tracking system for a solenoidal detector will be presented. The tracking system consists of a silicon pixel and microstrip detector at smaller radii from the beam collision point and wire chambers at larger radii. The tracking system provides momentum measurements and a fast trigger for all charged particles with p_T above a few GeV/c and for $|\eta| \leq 2.5$. Research and development issues will be discussed.

Introduction

The goals of a tracking system for the SSC are to provide momentum measurement and a fast trigger for charged particles with p_T above a few GeV/c and $|\eta| \leq 2.5$. In addition, the tracking system should provide a precise vertex measurement in order to identify long-lived tracks, for example, from B decays, and detect separated vertices from multiple p-p interactions. Since the tracking system is only a part of the complete detector, it must provide these functions in an economical manner. The tracking system must operate in the high-rate environment of the SSC at and above the design luminosity.

We are engaged in detailed design studies of an integrated tracking system[1] for a solenoidal detector for the SSC. The tracking system consists of a silicon pixel and microstrip detector[2] at small radii from the beam collision point and wire chambers at larger radii. The R&D includes wire chamber detector design for straw tubes and intermediate angle tracking detectors with wires transverse to the beam direction, engineering R&D including support structure and alignment, front end and triggering electronics, and computer simulation.

Tracking System Design

A conceptual design of the tracking system, contained inside a 2 Tesla solenoidal magnetic field, is shown in Fig. 1. The inner radius of the coil is located at a radius of 1.7 m, and the tracking volume half-length is 4.0 m. In order to aid the pattern recognition in the high-rate SSC environment, the entire tracking system design, except for the pixel detector, is based on the concept of track segments, rather than individual track hits. Track segments in the outer tracking system (radius > 50 cm) are used in the first level trigger. Track segments in the superlayers are linked to form tracks.

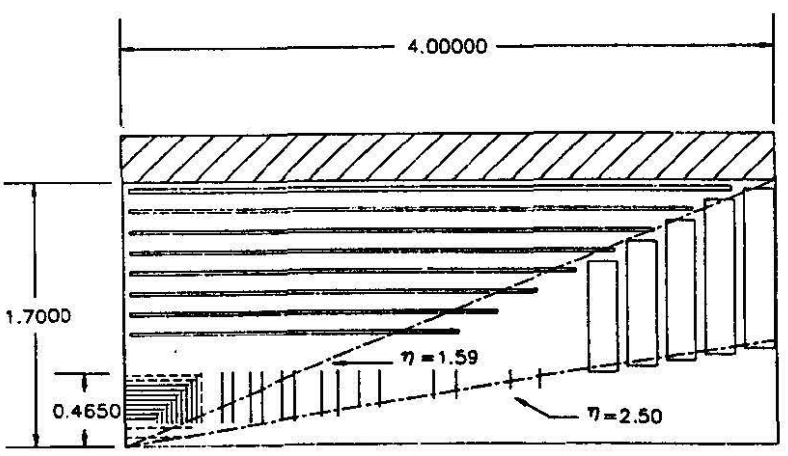

Fig. 1. Conceptual design for a silicon and wire chamber tracking system for a solenoidal detector.

The silicon tracking detector, inside 50 cm radius, consists of an array of high-resolution two-dimensional pixel detectors and segmented microstrip detectors; these provide vertex measurement and pattern recognition capability even in the cores of dense jets.[3] Some of the microstrip layers are double-sided silicon with axial strips on one side and stereo on the other. Track segments are found in superlayers consisting of two layers of silicon.

Wire chambers are used for tracking between 70 and about 163 cm radius. The central tracking system, covering the region $|\eta| \leq 1.5$, consists of superlayers of 4 mm diameter straw tubes[4], as shown in Fig. 2. In order to reduce radiation damage and current draw, the straws are made as small as practical and run at low gas gain, $\sim 2 \times 10^4$. Occupancy is reduced by the small straw diameter and the use of a fast gas, such as mixtures containing CF_4.[4,5] The half-cell stagger between layers permits resolution of left-right and crossing-time ambiguities. The coordinate along the wire is measured by means of small-angle (~3°) stereo. With a spatial resolution of 100-150 μm per wire in the r-ϕ projection, the expected resolution in z is 2-3 mm. The superlayers alternate axial and stereo. Local track segments are found in each superlayer.

The intermediate angle tracking system[6] covers the region of radius > 50 cm and $|\eta| > 1.5$. It is composed of drift chambers with wires transverse to the beam direction and "crossing taggers," as shown in Fig. 3. A crossing tagger is set of planes of gaseous proportional detector with cathode strip readout. Crossing taggers are used to associate a wire chamber hit to within 3 or 4 bunch crossings and could be used for the trigger. The wire chambers are presently envisaged to be radial wire chambers.

The performance of the tracking system is shown in Fig. 4.

Engineering R&D

The tracking system will be supported and aligned using a structure of graphite fiber composites.[7] There are inner and outer support cylinders for structural stability. The superlayers in the central tracking system are made up of modules of straws with an outer graphite composite shell to provide rigidity and positioning. The replaceable modules are positioned and supported by an open framework. The intermediate angle and silicon tracking systems are supported by the same structure.

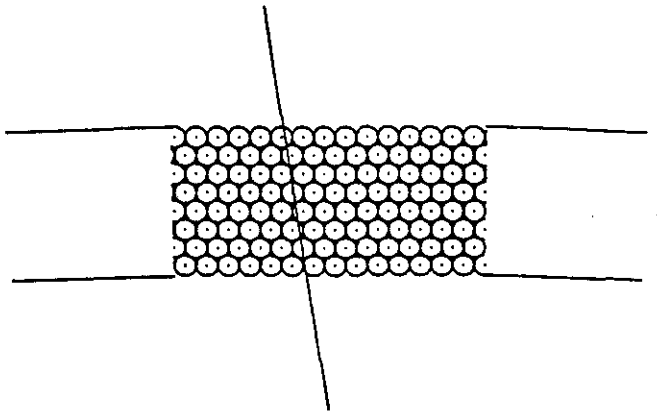

Fig. 2. Cross sectional view of a superlayer of straw tubes.

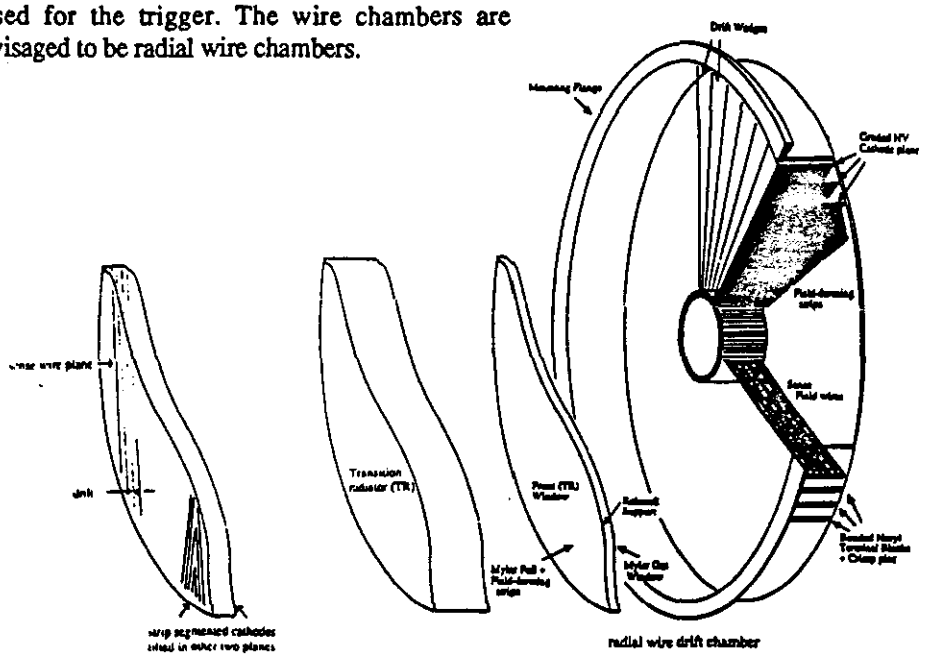

Fig. 3. Intermediate angle tracking supermodule layout.

Front End and Triggering Electronics

Custom integrated circuits for the front end and triggering electronics are being developed both as part of this subsystem effort and as part of separate electronics subsystem R&D projects. A low-power radiation-hard integrated preamp, shaper, discriminator and time-to-voltage converter are being developed as part of an R&D program centered at the University of Pennsylvania.[8] Similar developments are taking place in Japan. Circuits for triggering on track segments in superlayers using drift time (synchronizers) are being developed at the University of Michigan.

R&D Issues

The R&D issues involved in the design of the tracking system are being addressed by design and prototyping, as well as computer calculations and simulations. Some of these R&D issues are summarized below.

In the design of the tracking system, we must minimize material (primarily because of the problem of photon conversions) and cost. Materials issues include sufficient rigidity and structural support in the module walls and support structure, and connections to the wires at the endplates, including terminations, wire-holding devices, interface boards, electronics, and cabling. Finite element analyses are carried out to optimize the designs of the module walls and the support structure. Design and prototyping are being carried out to minimize material at the wire connections.

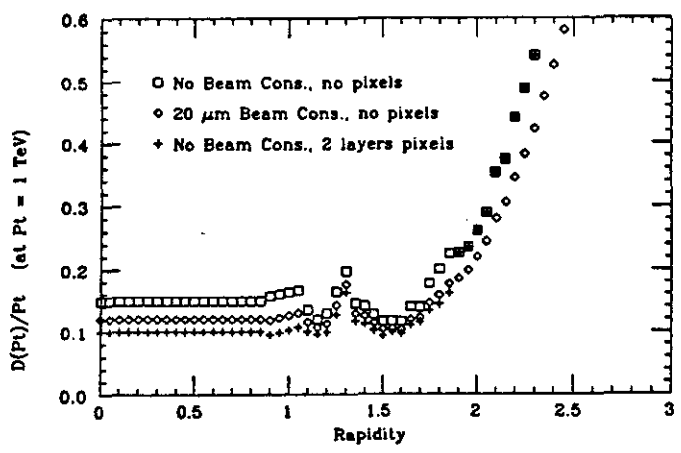

Fig. 4. Momentum resolution in a 2 Tesla magnetic field as a function of $|\eta|$ for the tracking system.

Wire chamber design and prototyping are being carried out for both the straws and the radial wire chambers. These studies include minimizing the resistance of the straws and determining the optimum technique for supplying graded high voltage to the cathodes for the radial wire chambers. Tests of suitable fast gases are being carried out. In addition, there are many construction and assembly problems to be solved.

We are building prototypes for all of the components of the design: straw modules, radial wire chamber sectors, connections, electronics, and support structure. These will be tested in a beam when possible.

Many crucial design issues are being addressed by computer simulation of the response of the detector to SSC background and physics events. With 16 ns between bunch crossings and 1.6 interactions per bunch crossing at the SSC design luminosity, high occupancy and its result, lost hits, are a major issue for wire chambers. We are using simulations to determine the best configuration for triggering on track segments in the outer superlayers of the central tracking and in the crossing taggers of the intermediate angle tracking. We need to continue to trigger on track segments as the luminosity increases beyond the design value, and we must do this with a sufficiently robust trigger using a minimum number of channels and at a minimum outer radius for the tracking system. We are also carrying out studies of pattern recognition for finding tracks.[9]

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2. "Subsystem R&D Proposal to Develop a Silicon Tracking System," A. Seiden, contact person.
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4. H. Ogren, "Wire Chamber Tracking," in these Proceedings.
5. J.A. Kadyk *et al.*, in these Proceedings.
6. J.B. Dainton *et al.*, in these Proceedings; D.H. Saxon *et al.*, in these Proceedings.
7. R. Swensrud, in these Proceedings.
8. L. Callewaert *et al.*, in these Proceedings.
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SDRC I-DEAS 4.1: Object Modeling

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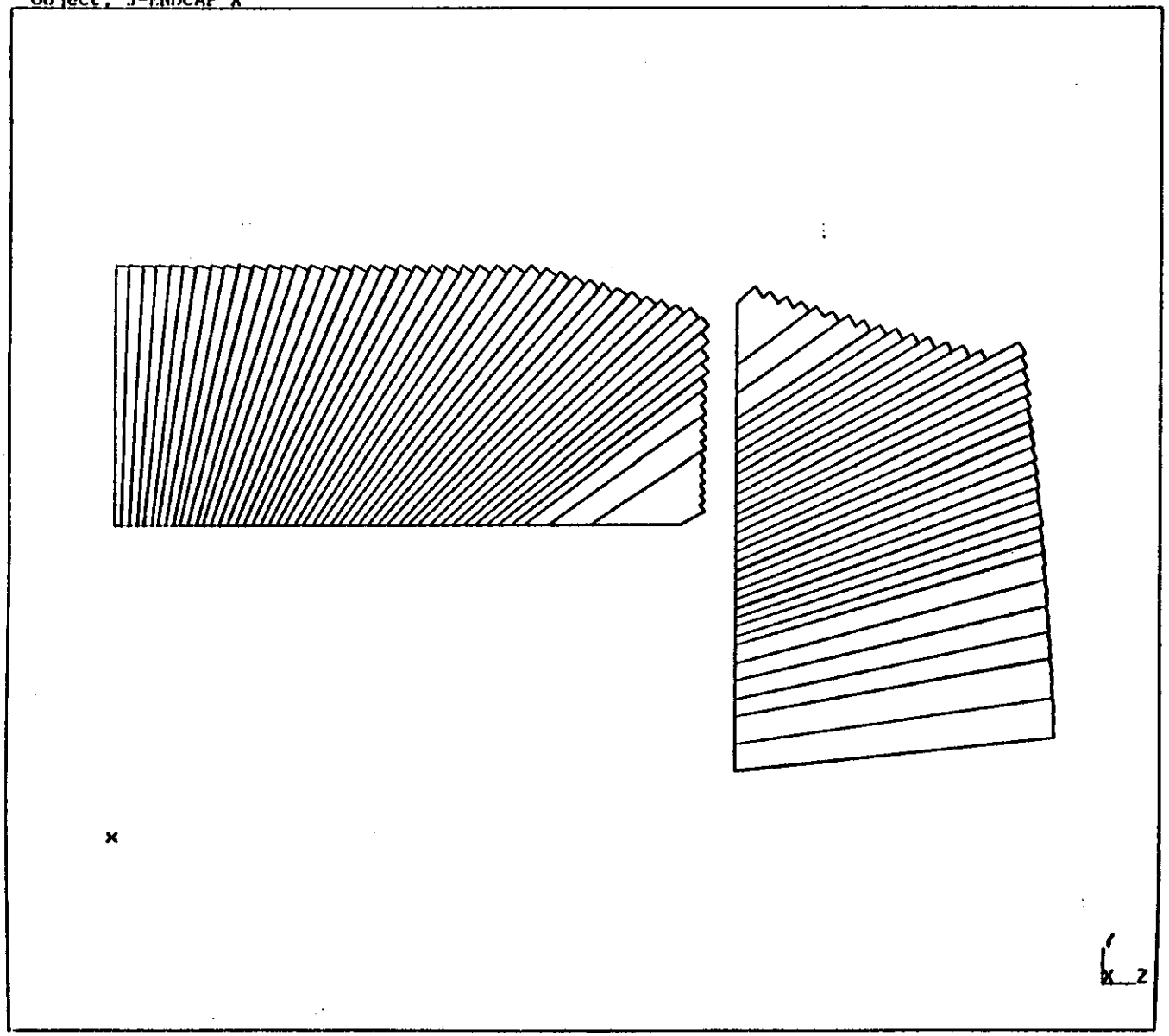

Fig. 1

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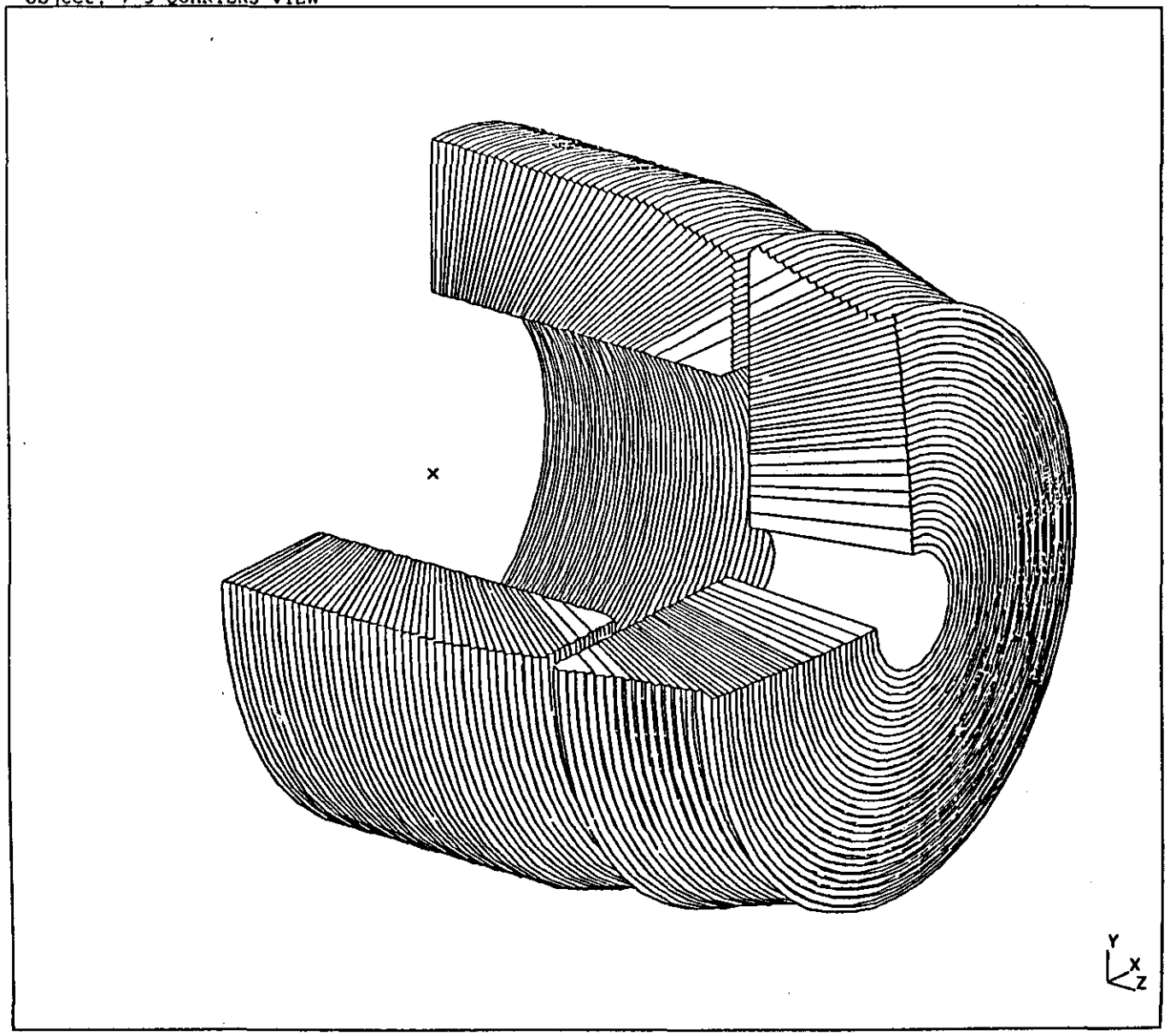
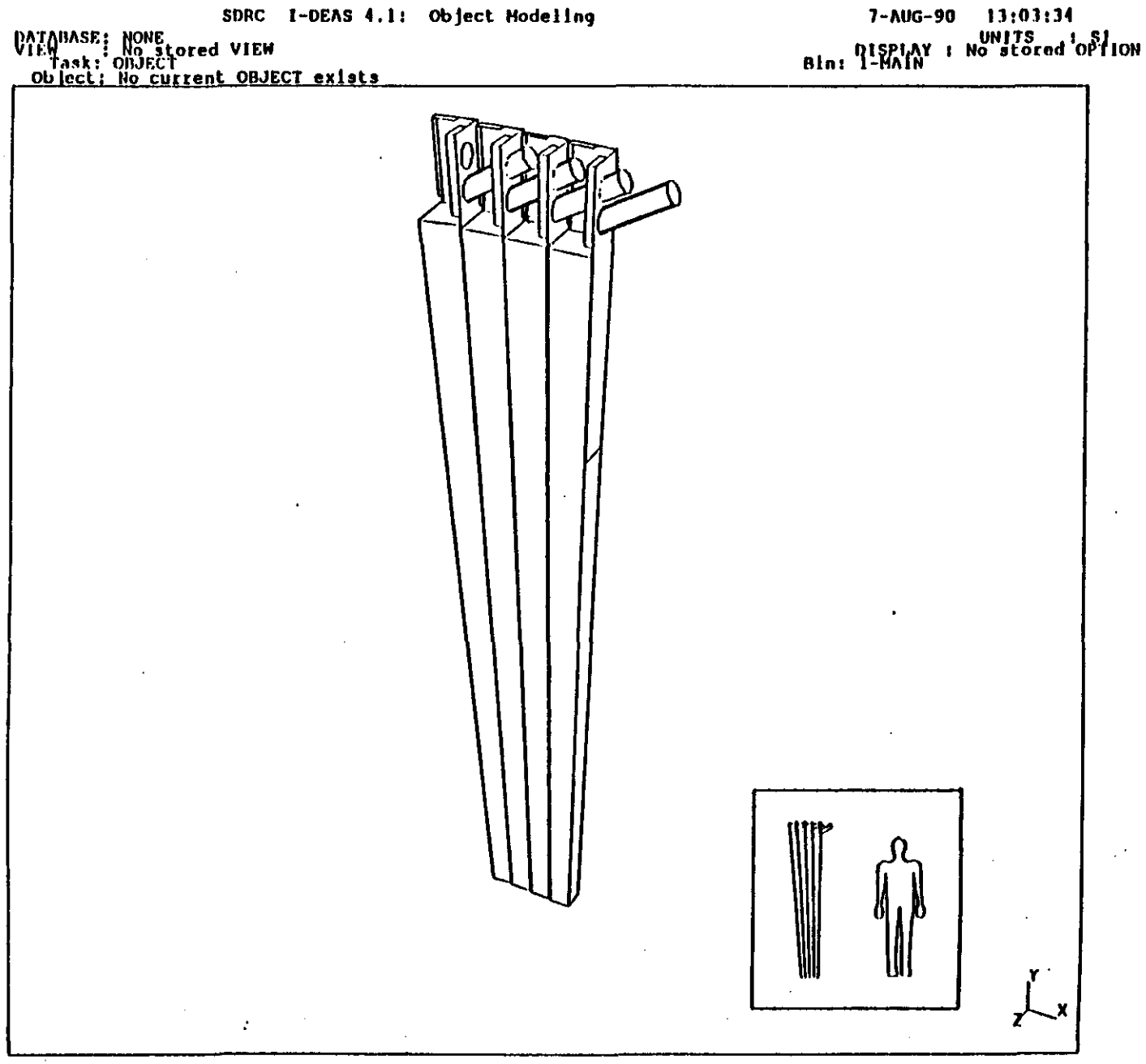


Fig. 2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Y
Z
X

Fig. 3

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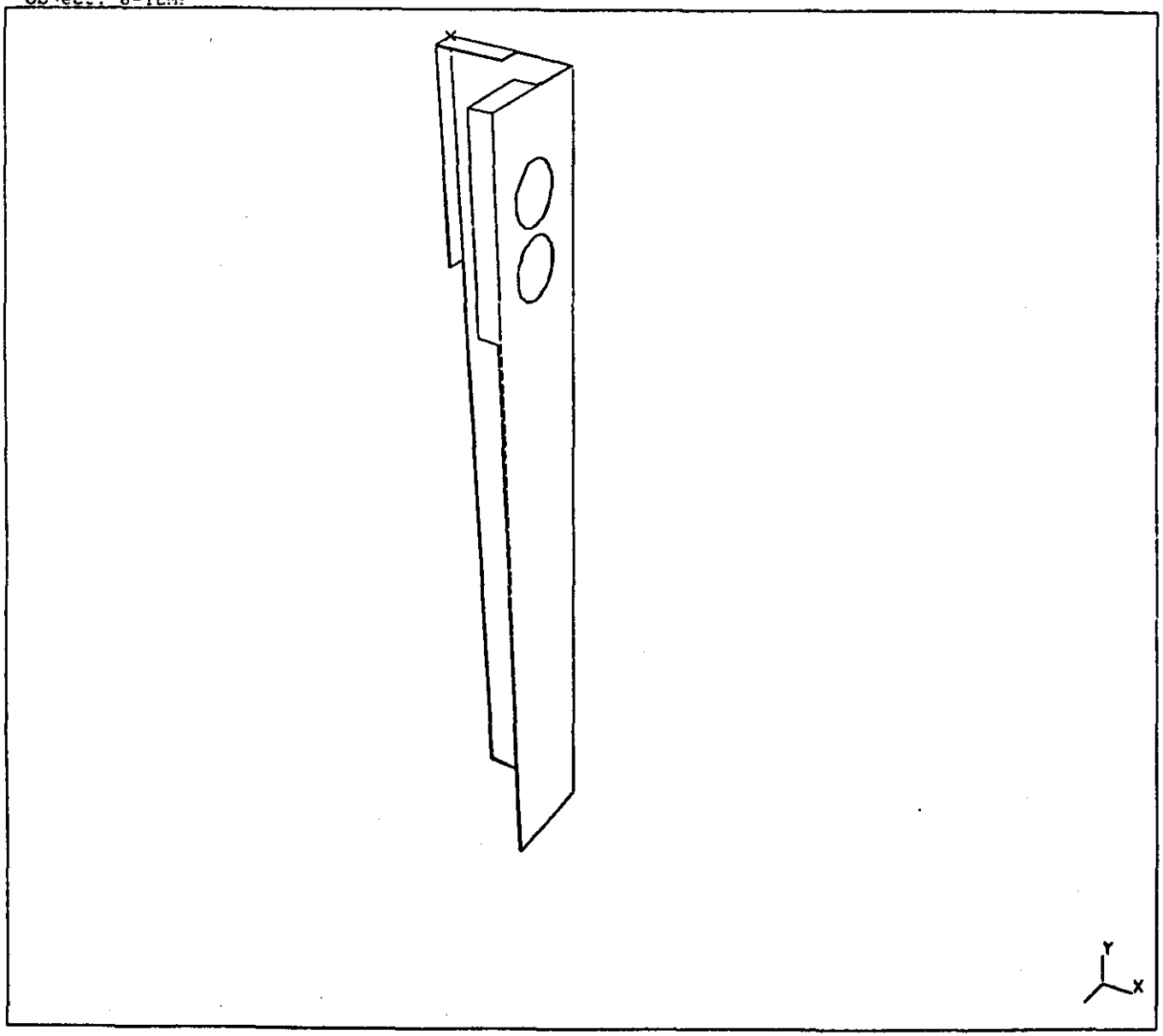

Fig. 4

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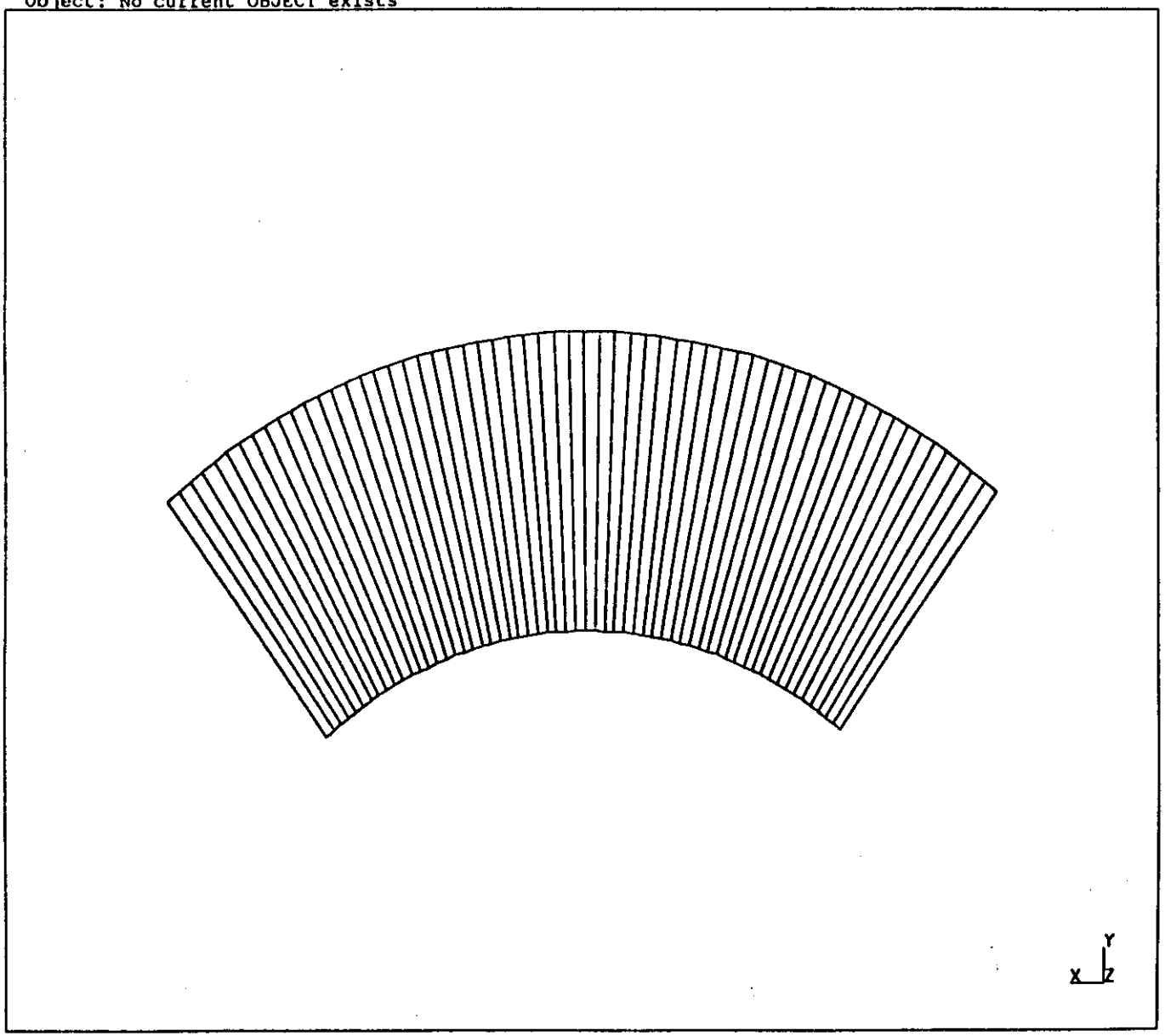

Fig. 5

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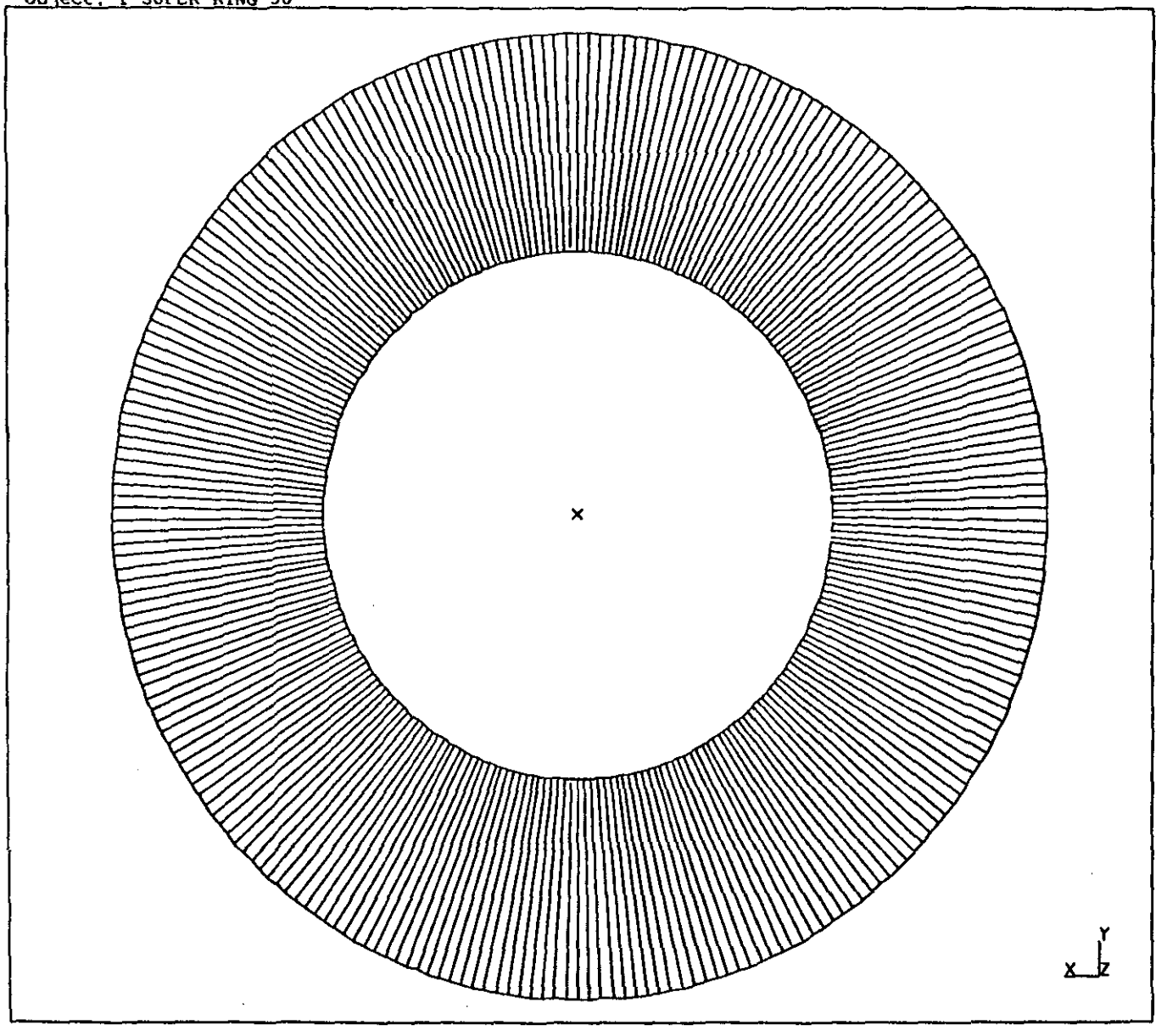

Fig. 6

SDRC I-DEAS 4.1: Object Modeling

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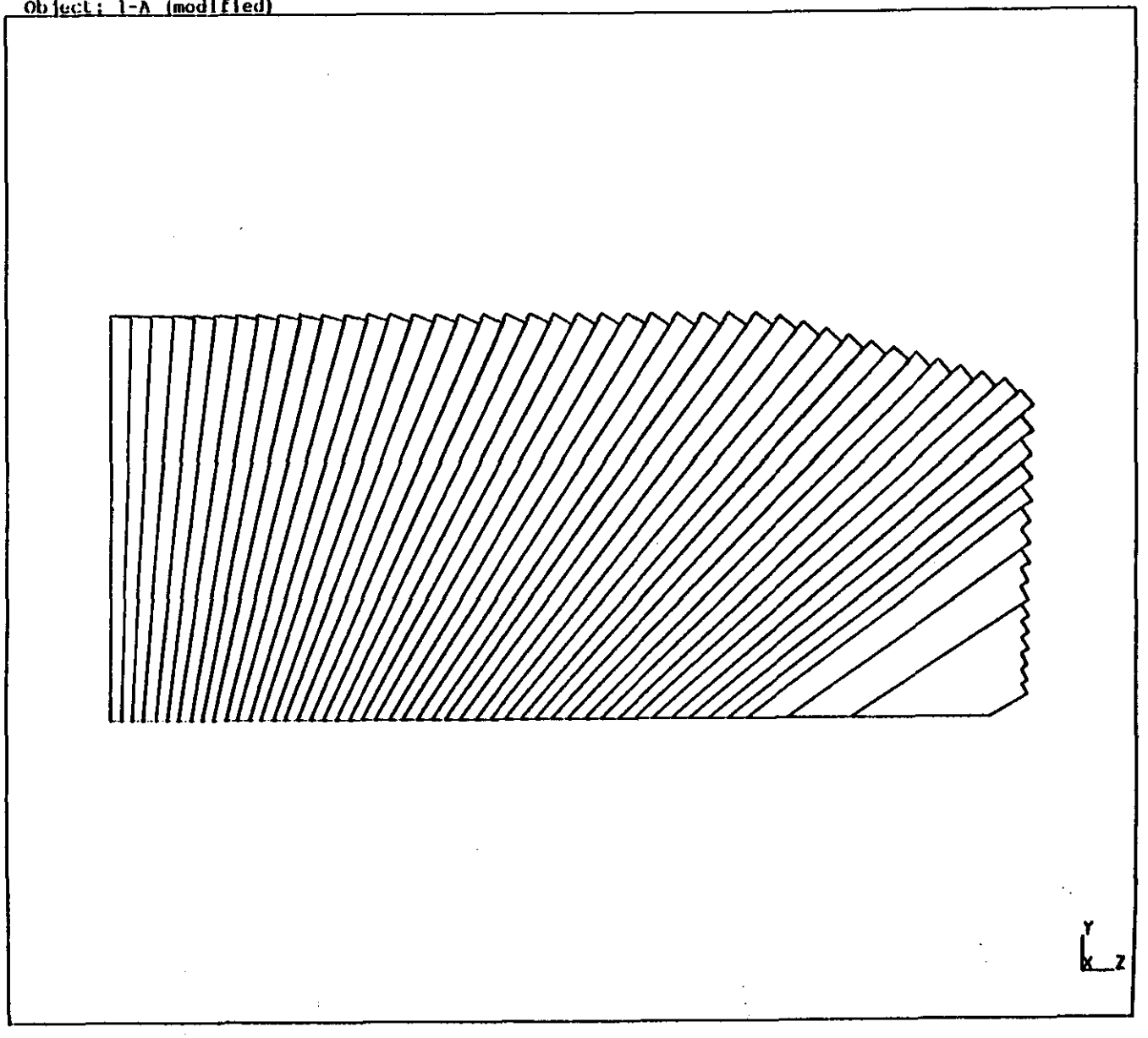

Fig. 7

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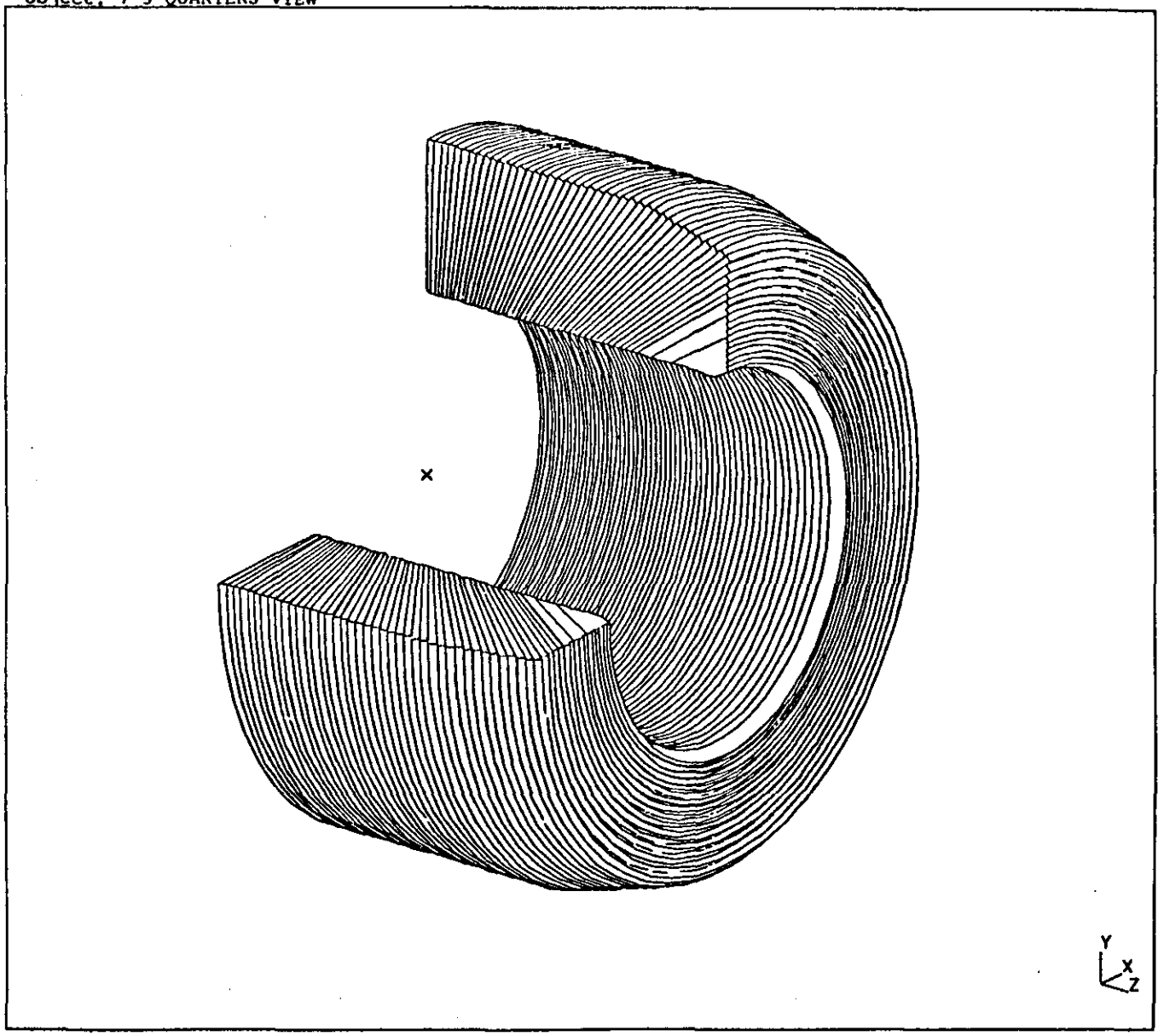

Fig. 8

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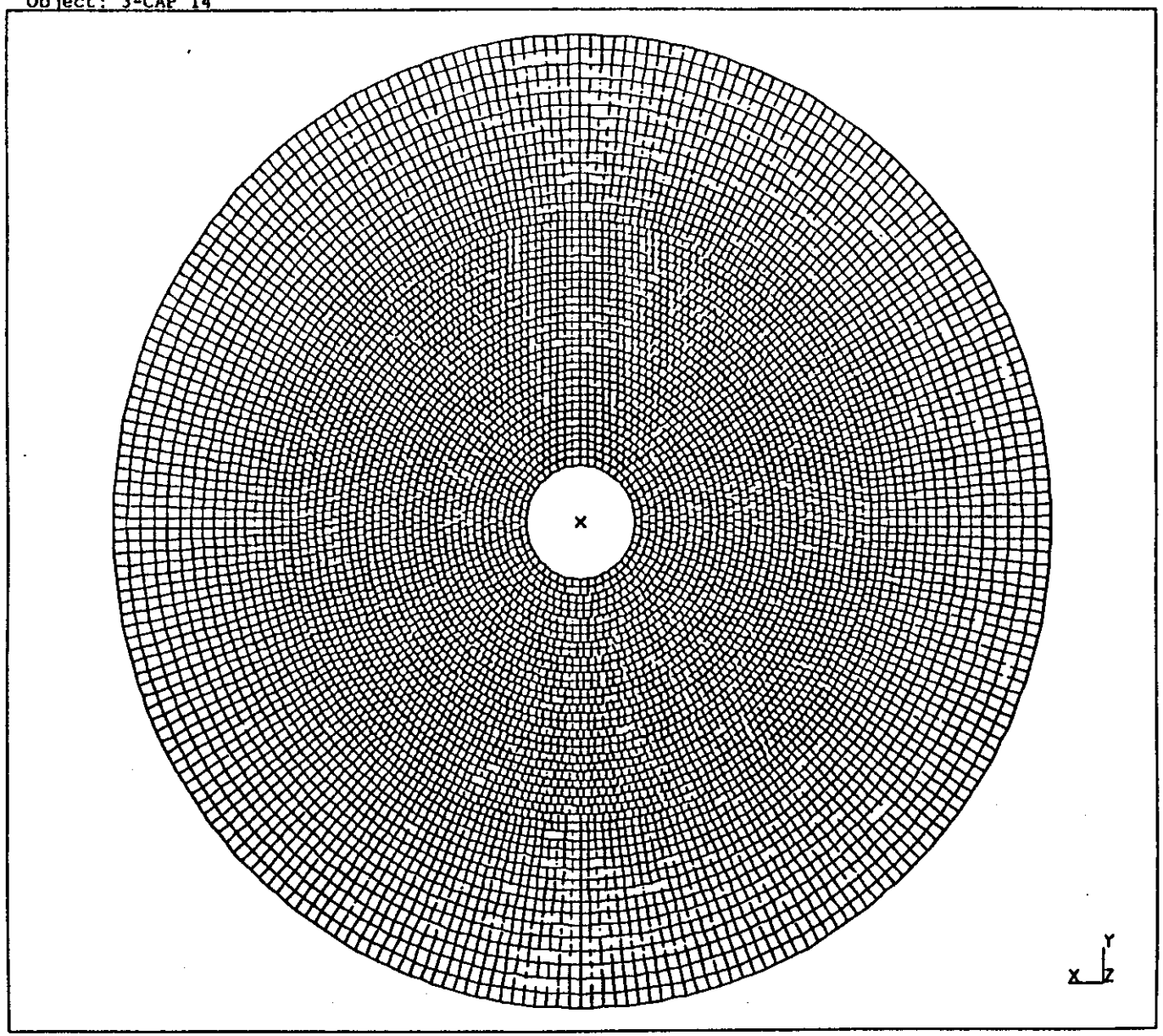

Fig. 9

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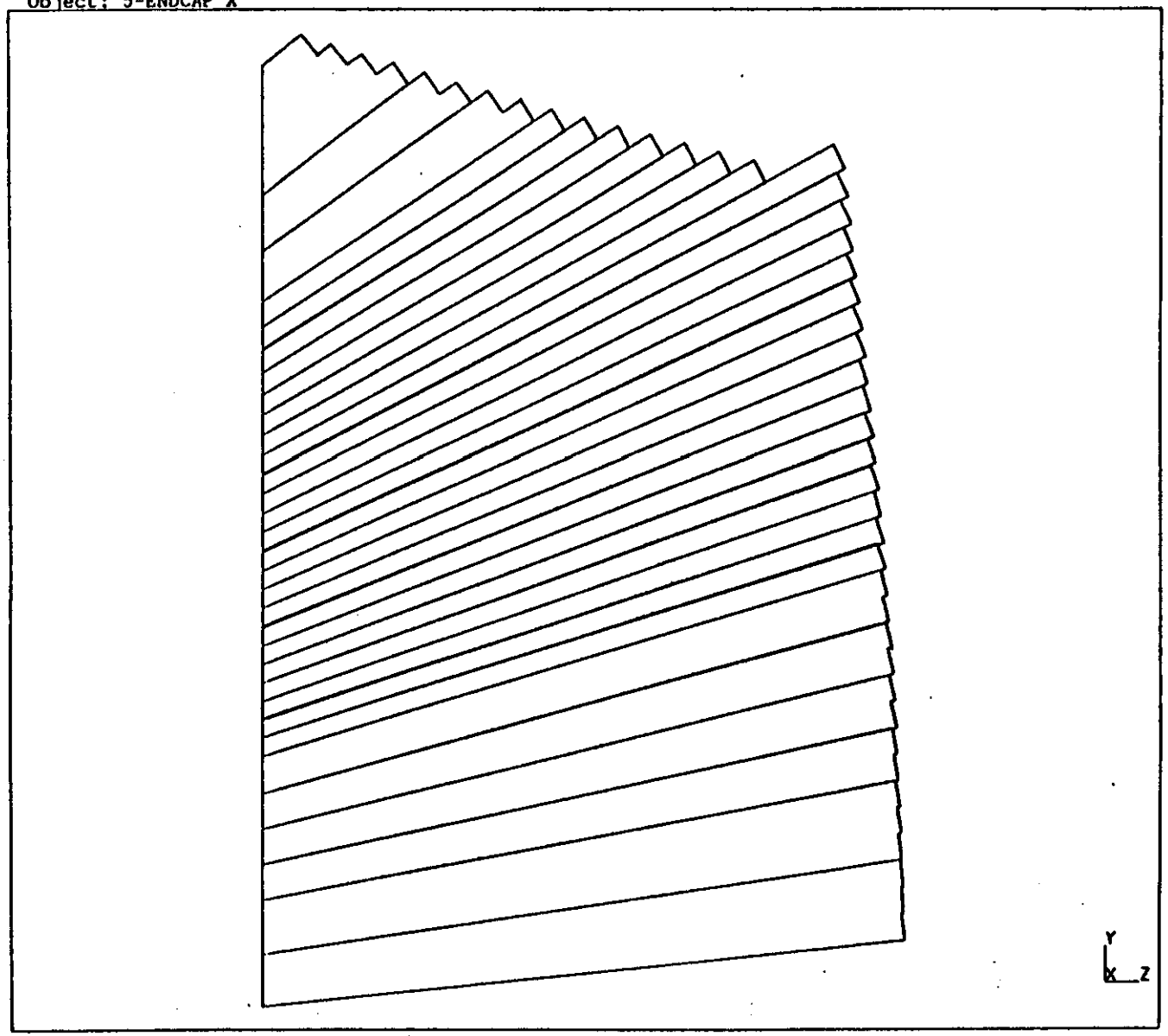

Fig. 10

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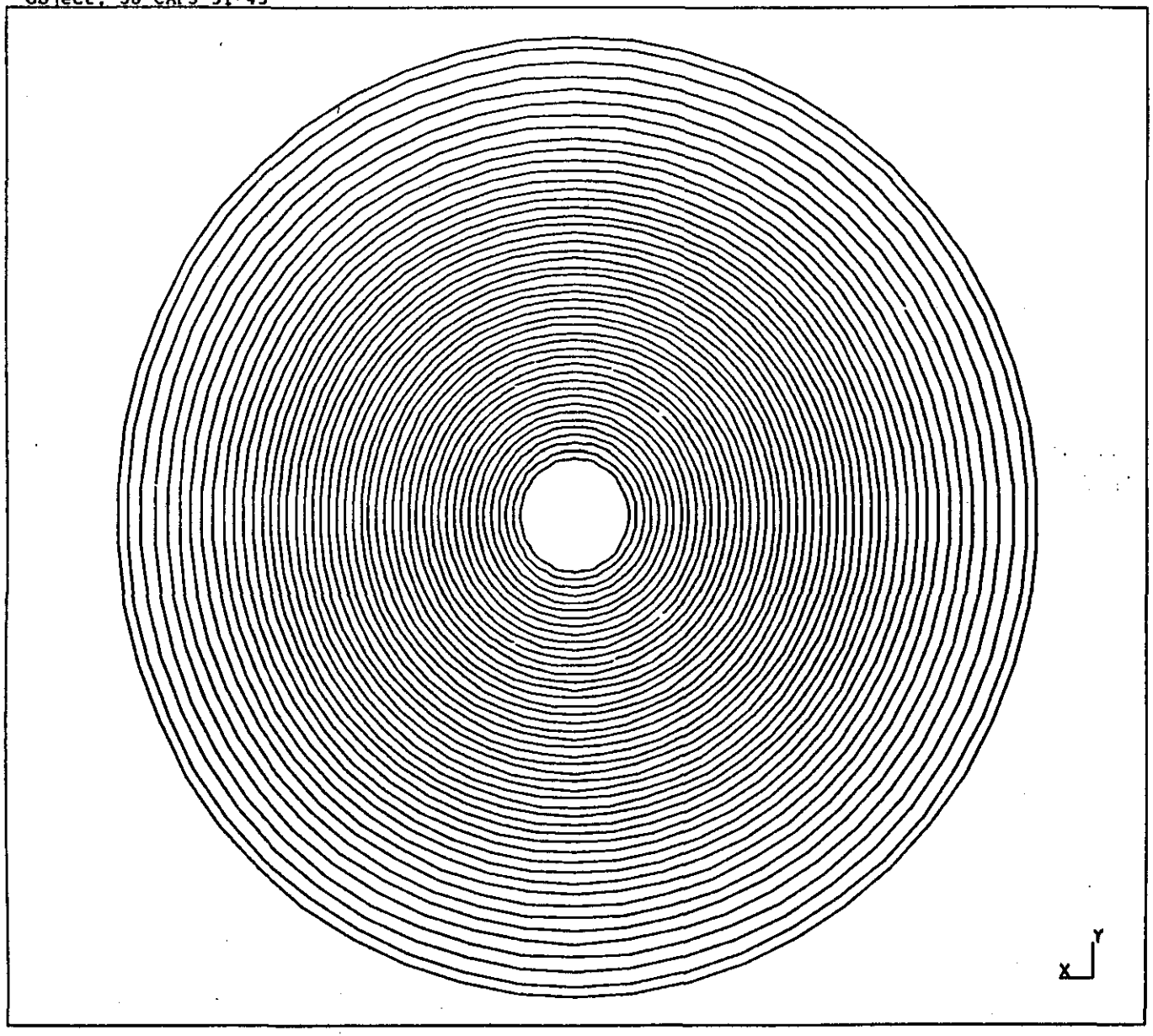

Fig. 11

SDRC I-DEAS 4.1: Object Modeling

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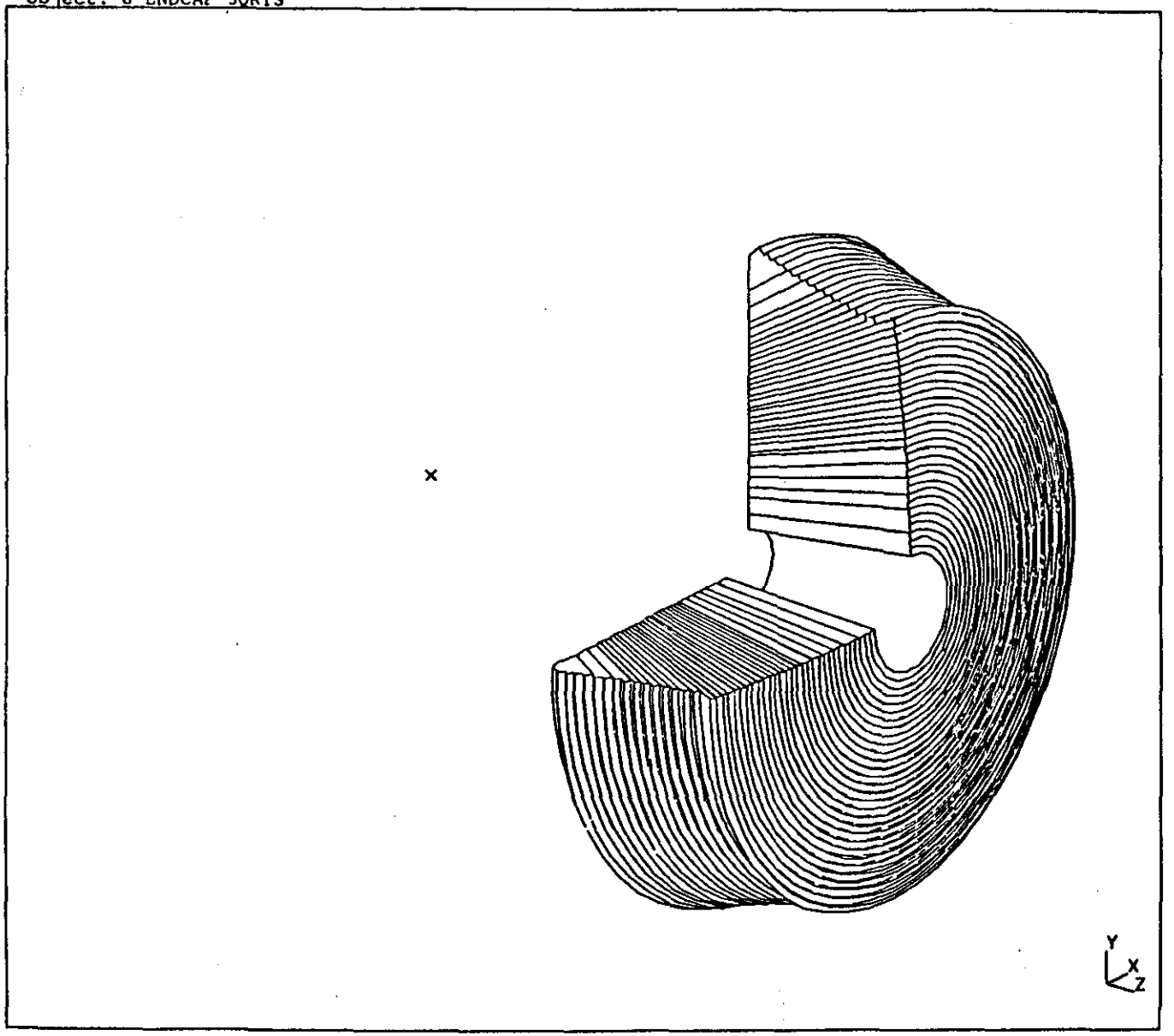

Fig. 12