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ELECTROFORMING CELL DESIGN TOOL DEVELOPMENT

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ABSTRACT

The Electroforming Advisor (EFA) team has developed a prototype of an EFA, an easy-to-use design and computational problem solving environment for electroforming. A primary goal is to enable electroformers to optimally design a cell that would make a part right the first time and with minimum cost. Computer simulations can be carried out much faster than experimentation and without hazardous waste production. The EFA prototype uses the Computer-Aided Design (CAD) and the Computer-Aided Engineering (CAE) capabilities of the Intergraph Engineering Modeling System coupled with the simulation capabilities of a locally developed three-dimensional boundary element code, BEPLATE.

INTRODUCTION

The purpose of this paper is to introduce the Electroforming Advisor (EFA) concept, show some of the productivity enhancements that are made possible by an advisor, and describe the development of the EFA. Electroforming is an electrochemical process for manufacturing freestanding parts by cathodically depositing metal on a mandrel. Electroforming can produce complexly shaped parts, with constant or varying wall thicknesses as needed, the manufacture of which would not be feasible using other methods. One surface of the electroform exactly copies the mandrel surface. Even fine, microscopic details of the mandrel surface can be replicated on the electroformed part. Precise control of the location (wall thickness) and surface morphology (roughness) of the opposite or growth surface is more difficult.

Development of electroforming process design and control is currently a laborious cut-and-try method involving multiple iterations of tooling design and fabrication experimental tests and evaluation of the product. For complex parts, several months may be required before production can begin. A highly experienced expert is required to do this efficiently. Considerable waste can be produced during this pre-production experimentation.

The goal of the EFA project is to provide the designer with a virtual EF cell that will allow much more effective electroforming (EF) cell design and optimization. The prototype EFA uses the power of a commercial

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system of codes that provides a seamless Computer-Aided Design/Computer-Aided Engineering (CAD/CAE) environment. The Intergraph Engineering Modeling system is a collection of layered products that are integrated into a smooth, easy-to-use Graphical User Interface (GUI) for engineering design work. This integrated system allows the user to describe a cell design rapidly. We have coupled the locally developed EF simulation code BEPLATE[1] with this powerful CAD/CAE environment and developed specialized modifications to this environment in order to provide a complete cycle of design, analysis, and evaluation to the user.

ELECTROFORMING ADVISOR

We envision an advisor to be an advanced design tool that combines traditional CAD with CAE and analysis functions in a seamless environment. The advisor should enable the design of an EF cell in an easy-to-use CAD environment that can be easily transferred to a CAE system. A CAE system contains an analytical model generation system (traditionally called a pre-processor), an analytical simulation system, and a results viewing system (a post-processor). Combining the CAD and CAE functions into one system allows the easy generation and modification of the model by CAD operations, transparent generation of an analytical model from this CAD representation, analytical simulation of the performance of the part (stress, heat transfer, etc.), and viewing of the results in the same environment. The first and most obvious benefit of this technique comes from the easy modification of the design and the rapid generation of a new model to be analyzed. The user controls the whole process from one environment, never leaving the EFA system. Most menus and actions are common between the CAD and CAE tools.

Creating an EF design tool in a seamless CAD/CAE environment allows the development of the tool into a true advisor system that incorporates expert system rules and logic to provide the user with a guide to designing the part. We intend to use such a system to capture knowledge from existing experts. Electroforming is an area ripe for this knowledge capture effort since so much of the EF cell design process involves experientially guided guessing. This guessing is shaped by many years of electroforming experiments based on trial and error. These experiments involve considerable time and effort to perform and produce a significant volume of hazardous waste. Thus, the capture of this knowledge before retirement represents a recouping of the investment of many years of costly experiments.

DEMONSTRATION

We have produced a short video that effectively demonstrates some of the power of this type of design tool by using the prototype on a test part. Since the video was produced, further development of the EFA has been completed. The added features eliminate some of the steps in the demonstration; therefore, the current version is much easier to use and much faster than the prototype.

The demonstration in the video is performed on a test mandrel (Fig. 1). This mandrel is a hemisphere with a short cylinder attached at the equator. The cylinder forms the base of the part and is bolted to a nonconducting flange for attachment to a rotating mechanism which is suspended above a square tank. The mandrel is suspended at the top of the of the electroforming tank (Fig. 2) with the pole of the hemisphere pointed down into the tank.

The demonstration in the video shows the generation of a simple region using the CAD interface. The associative dimensions in this CAD system allow simple modification of the model in subsequent design iterations.

The CAD model for the standard part suspended from the top of a square EF tank with four cylindrical anodes in the corners of the tank is shown in Fig. 3. This model is symmetrical about a plane that passes from the part center through an anode centerline; it is also symmetrical about a plane passing through the part center and in between a pair of anodes. The pie-shaped segment bounded by these planes (one-eighth of the full segment is the largest segment that is needed in the analytical tool. For computational efficiency, the discretized model is limited to this region. The symmetric segment model is shown in Fig. 4. A discretization of this segment is shown in Fig. 5. Discretization is necessary to provide the simulation module (BEPLATE) with specific geometrical information needed to do the analysis. Although these processes required several steps in the prototype, the generation of this symmetrical model and the discretization is now automatic.

The analytical simulation by the BEPLATE code is transparent to the user. After the simulation is completed, the results are ready for display. Figure 6 shows a current density distribution on all elements of the symmetric model and an expanded scale view of the symmetric surface of the part.

In the video, the ability to easily modify the cell design and reanalyze the cell is shown by altering the shield dimensions and by placing a set of four holes around the circumference of the shield. A set of analyses for different shield diameters is summarized in Fig. 7.

As the part grows thicker, the part surface changes, and the local current density can change significantly in response to this change in cell geometry. The BEPLATE code simulates this part surface modification by moving the elements that define the surface as a function of the local plating rate and recalculating this rate for the next time step. Thus the evolution of the part geometry is followed over the duration of the electroforming.

OTHER PART SHAPES

The EFA will allow the designer to model any part shape, and given certain limitations, its application is not confined to axisymmetric shapes. The current version of the EFA will produce geometric models for more general part shapes. We have also been successful in importing IGES and DXF files as part descriptions. It may be possible to import other descriptions (file formats).

We have only performed analyses for a limited number of part shapes and would be interested in modeling other part shapes, particularly if experimental electroforming thicknesses are available.

In the experimental electroformings on this part,[1] the rotation produces a turbulent boundary layer that modifies the local plating rate. This effect is included in the BEPLATE code, but only for axisymmetric parts rotated about the centerline. Other part shapes would have to be modeled assuming stagnant flow conditions. Development of a more capable fluid dynamics model is planned.

CONCLUSIONS

This EFA prototype demonstrates some of the productivity enhancements that are possible in a production advisor system. The seamless CAD/CAE environment provides a platform for the development of easy-to-use design advisor.

REFERENCES

1. G. E. Giles, L. J. Gray, J. S. Bullock IV, *BEPLATE—Simulation of Electrochemical Plating*, K/CSD/TM-89, Martin Marietta Energy Systems, Inc., September 1990.

Figures

Fig. 1. A test mandrel with mounting flange and electroformed part.

Fig. 2. An electroforming tank.

Fig. 3. CAD model of electroforming tank.

Fig. 4. Full tank showing one-eighth symmetric segment model.

Fig. 5. Discretization of symmetric segment model.

Fig. 6. Left: current density on all elements; right: cathode surface of symmetric segment model.

Fig. 7. Current density as a function of distance for several shield sizes.

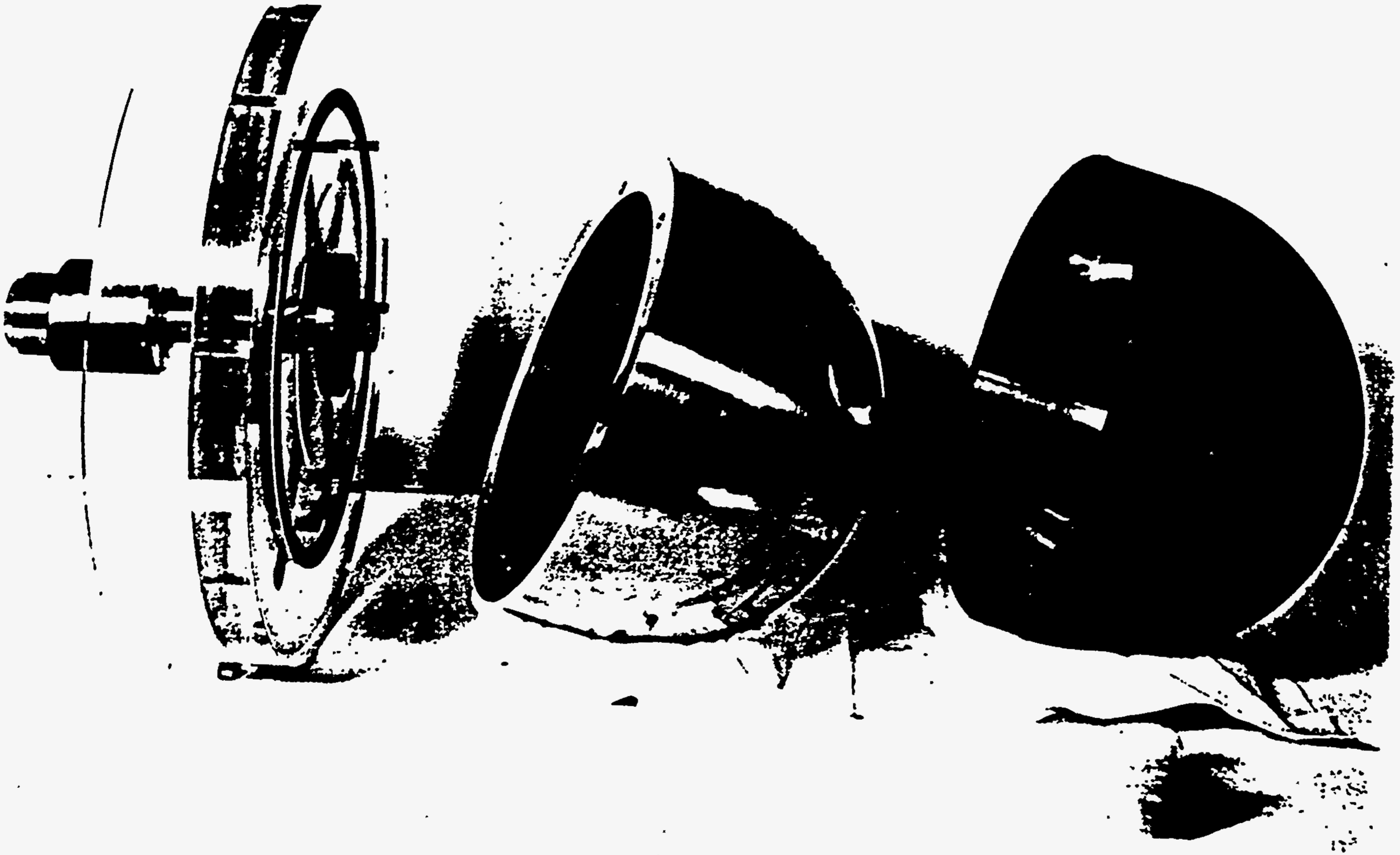

Fig. 1 Picture of test mandrel with mounting flange and electroformed part.

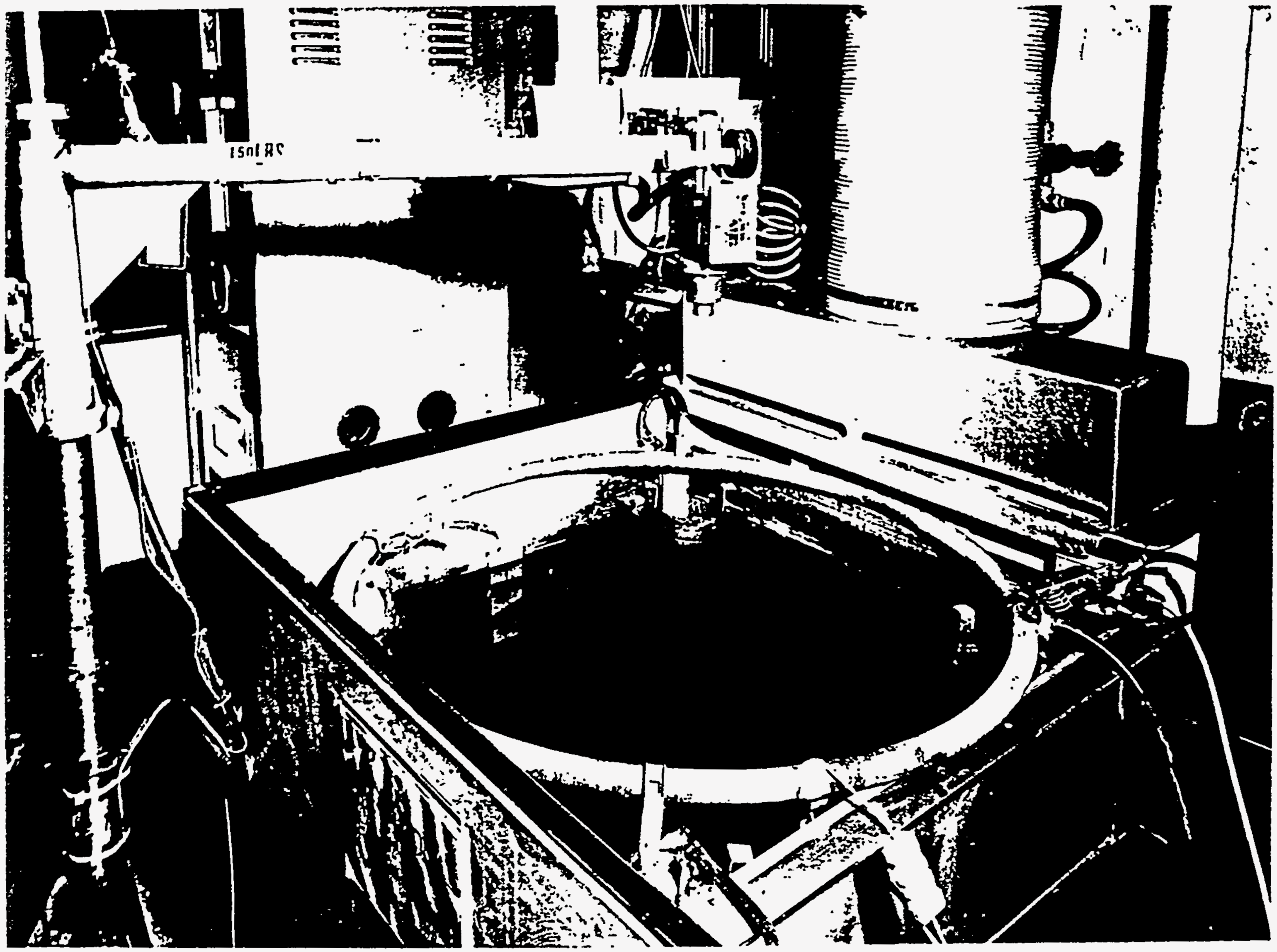

Fig. 2 Picture of electroforming tank.

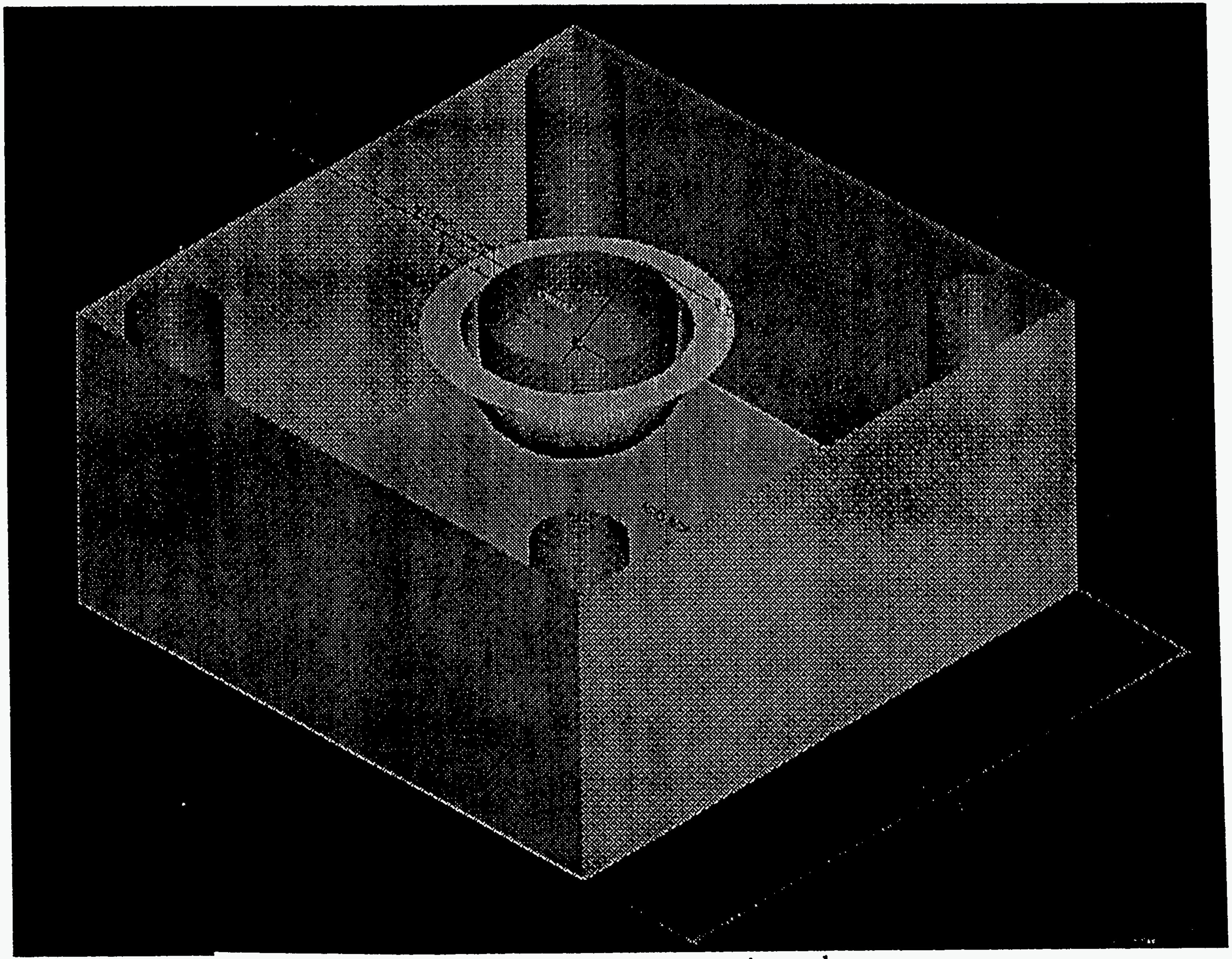

Fig. 3 CAD model of electroforming tank.

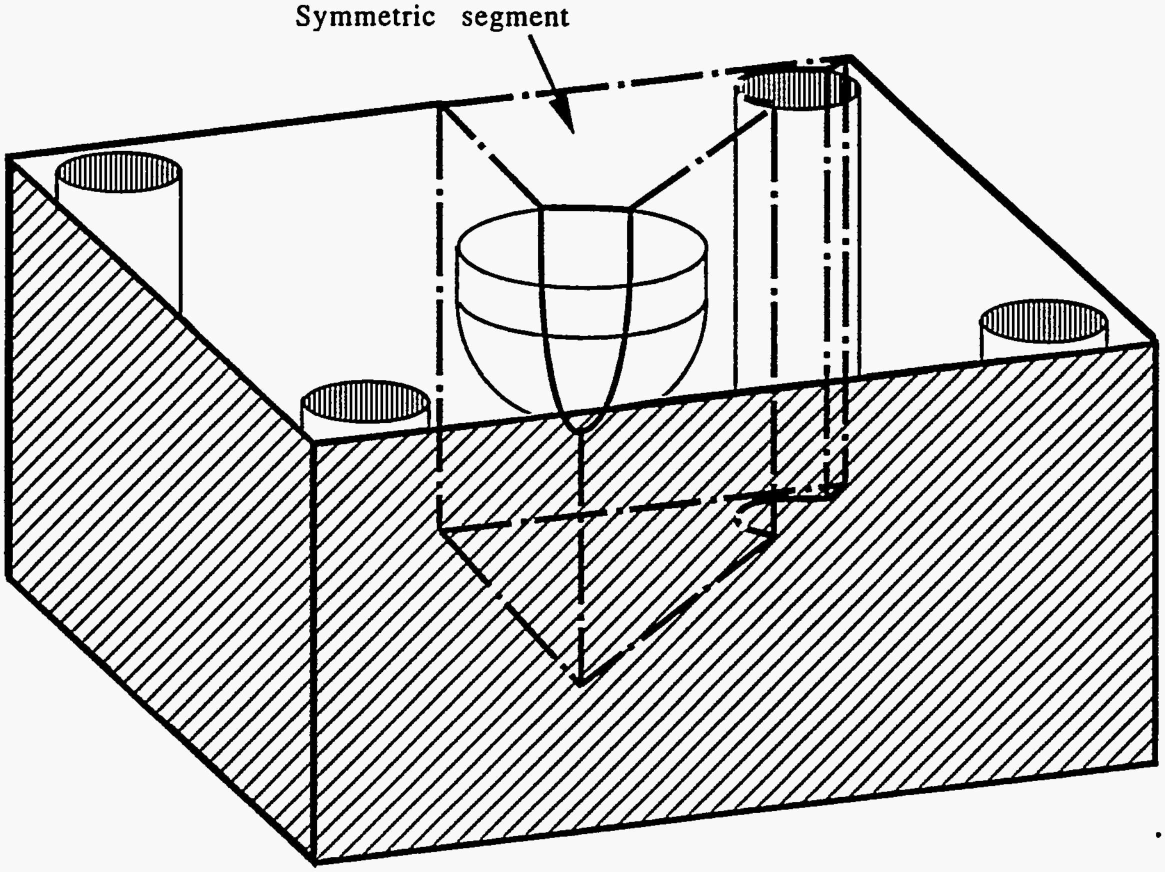

Fig. 4 Full tank showing one-eighth symmetric segment model.

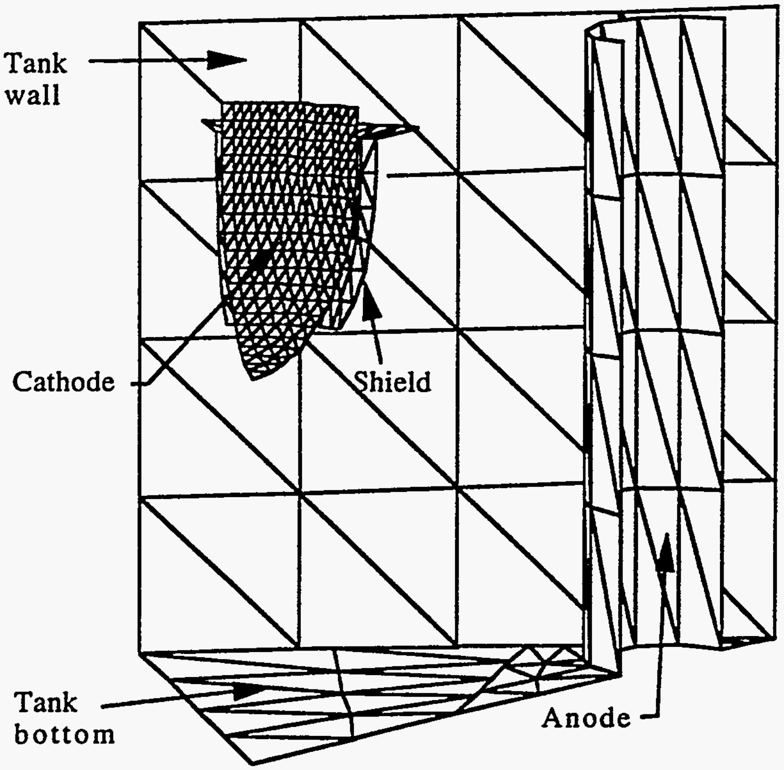

Fig. 5 Discretization of symmetric segment model.

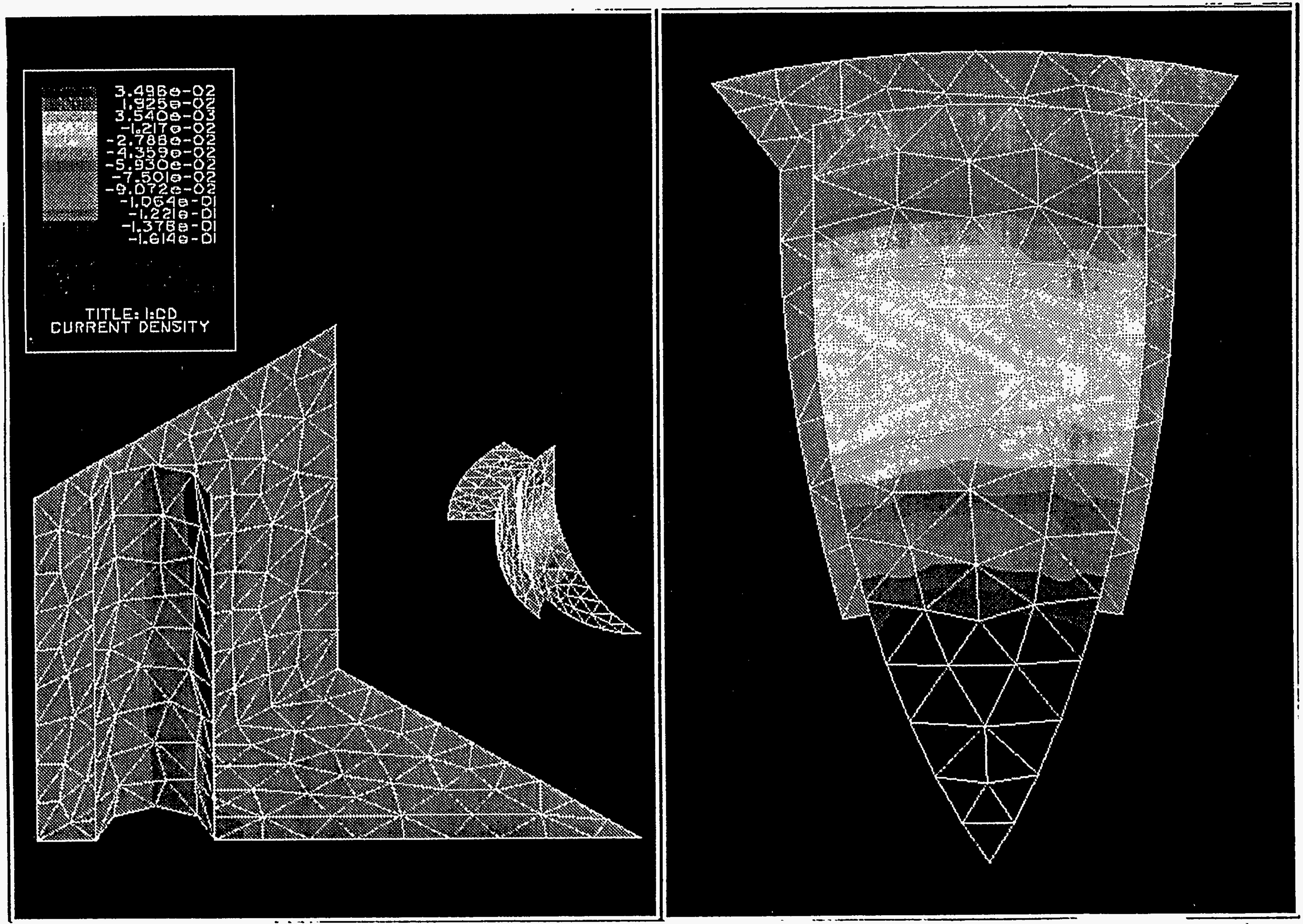

Fig. 6 Current density on (left) all elements and (right) cathode surface of symmetric segment model.

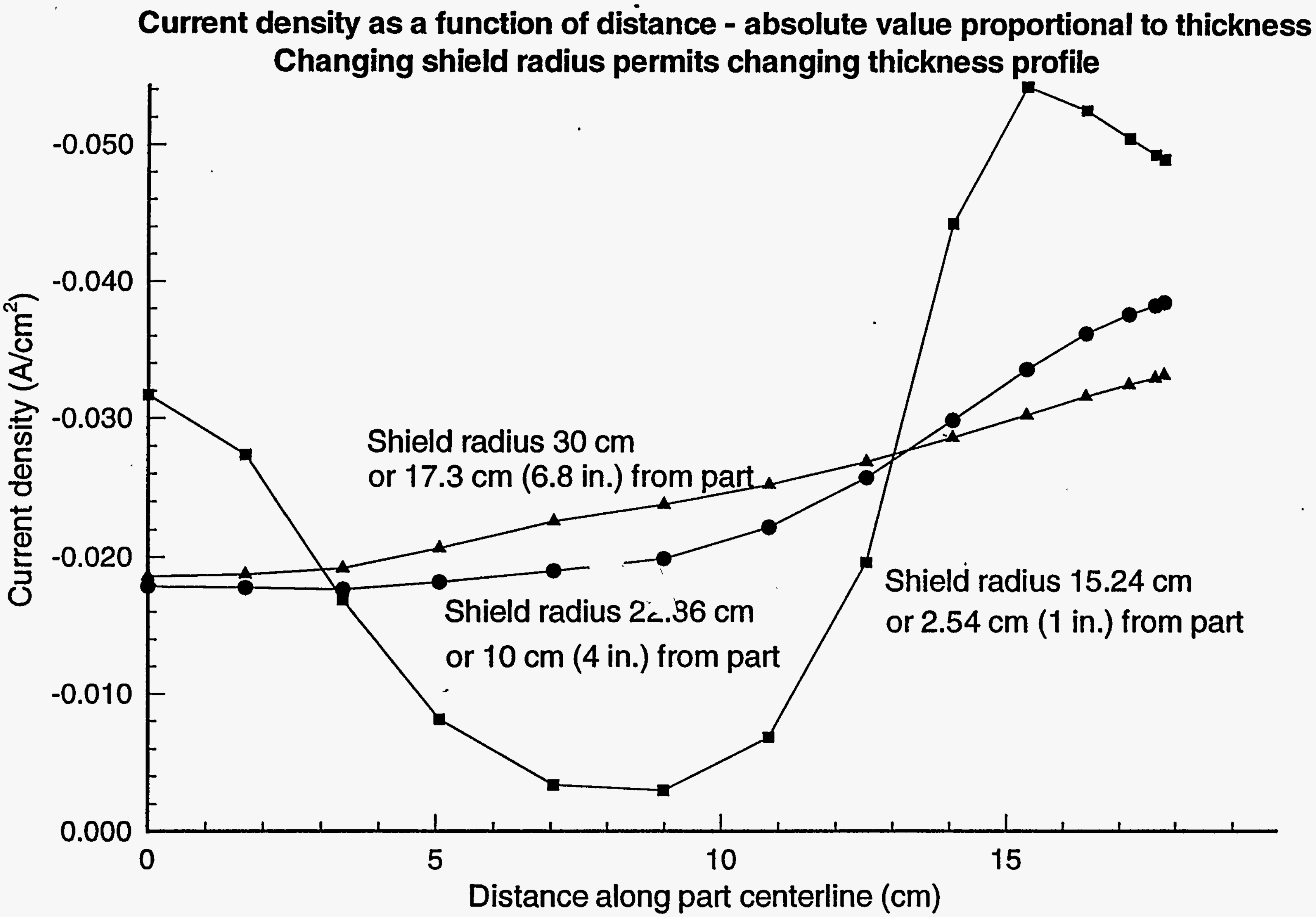

Fig. 7 Current density as a function of distance for three shield sizes.