T E C G R A P H

Technical Computer Graphics

A Program Package for Computer Aided Design

By Thomas P. Koehler, Atlanta, Georgia

1 Abstract

The purpose of this paper is to give a brief survey about the theoretical background and the capabilities of the TECGRAPH system for computer aided design in engineering.

The concept of this new program package is designed to help engineers doing routine work such as plotting and calculations. By using a new concept for the description of the objects and for the processing of the data developments for numerous applications in engineering are possible.

The data description works strictly according to set theory. Thus, it is very easy to learn how to describe an object. Moreover, the use of the program is quite simple. The only prerequisite is that the user should be able to imagine how the object looks. If he is not, he should at least have a rough draft. There is no computer knowledge necessary.

The programs are written in standard FORTRAN IV.

2 Introduction

The purpose of the TECGRAPH program package is to give the engineer a tool to help him in doing his routine work. The development of the program started from a mechanical engineering background, but the applications are not restricted to this field.

The program package is very easy to use and very robust. All possible error conditions are checked, so that the program cannot blow up by incorrect input data. The TECGRAPH command language is very easy to handle and requires absolutly no computer knowledge. The commands are basically self explanatory. Short command descriptions can be obtained interactively and the error messages provide a short explanation of the error condition.

The layout of the program also allows its application also on very limited computer mainframes, as the HP - 1000. It consists of a total of about 5000 lines and needs a maximum of 45K core memory.

The program is written in ANSI FORTRAN IV and is therefore highly transportable. The minimum word length of the CPU is 16 BIT. The same version is installed currently on mainframes of all sizes (HP 1000, PR1ME 400, CYBER 74).

The developments of the program were done by the author basically without the knowledge of other developments. Literature studies of the last months showed, that large parts of the program are absolutly new and without precedent in the open literature.

3 Object Description

The description of the objects is strictly according to set theories. The object is described as intersection, union and inversion of volume elements. Volume elements may be either user defined (as intersection, union or inversion of other volume elements) or may be elementary volume elements. Elementary volume elements are volume elements which are limited by elementary surfaces. Such elementary surfaces are planes, spheres, cylinders and cones. Elementary volume elements usually reach to infinity. Therefore they have to be limited by intersections with other volume elements.

This is the most universal way of a data description based on set theory. there are absolute no resrictions to this way of description.

To describe an object, the user defines the main axes of the object in a rectangular coordinate system and uses these axis then as relative coordinate system to describe the elementary surfaces. With the description of the elementary surfaces the elementary volume elements are also defined. The only work left to do then is to build up the user defined volume elements. By that, the structure of the object is defined.

Every axis, volume element or surface is stored as one element in the data base and is associated with a name unique in the data base.

4 Data Base

The data base is a direct access file. Therefore the data base routine for open, close, get and put are very environmentally dependent and must be rewritten for every installation.

The data base contains the full description of one or more objects. Different objects may share information. The structure is rather a network than a hierarchy. Every element may be accessed directly by specifying its name without passing through a long structure. There are no restrictions for the access of an element in the data base.

An additional feature of the data base structure is the high transportability. The data base may be dumped on tape and transported e.g. from an HP - 1000 mainframe to the CYBER 74. The dump is done by the TECGRAPH file management subroutines and requires only one command to be invoked. The same is true for the restore routines. There are no adjustments necessary; and the data base may be processed on the other mainframe as a data base created in this enviroment.

Transportable data bases are very important for data exchange, e.g. between companies. Therefore it is very surprising that there are no other CAD systems, to the author's knowledge, which have this feature.

5 Command Language

To handle the different services provided by the TECGRAPH program package there is an extensive command interpreter available. For the convenience of the user, the commands, parameters for every command and the error messages are stored in a file, which is read at the beginning of each TECGRAPH session. This allows the user to adapt the name of different commands, the names for the parameters and even the text for error messages to his own requirements. This allows also a very easy translation of the command language into another language.

Every command has the form command, element in the data base which is to be manipulated and the parameter. If either command or element name are omitted, the previous one is assumed.

For the convenience of the user only the first two letters of a command are significant. Multiple commands on one line are possible.

There is an option available, which prints every command the way the command interpreter understands the command. This is a very convenient feature in tracing down input or typing errors.

Error messages have the form error code, program section, in which the error occured and a short explanation of the error.

6 Editor

The program editor provides services for defining and editing of an object and for file management. As a result of the previously described command language the services of the editor are very easy to handle. There are commands available to define new volume elements and surfaces. The section list control allows a dump, in an easily read format, of the whole data base or part part of it, either on the terminal or in the file PROTO for printing on a line printer.

The services in the section file management contain routines to create a new data base or to open an existing one.

The commands SAVE / RESTORE allow the saving of the data base or the restoration of a previously dumped data base. The data base is dumped into an sequential file in ASCII format with 80 characters per line. By this the file may be saved either on tape or even on cards.

7 Plot Program

The plot program is currently the only utility program using the object as described in the data base.

It is a program with many options. Plots may be produced from one object or several objects at the same time. The sheet is considered as a window to cut off parts which are not of interest. This allows plots of details or of objects which actually still reach to infinity.

Plot program

The plot may be done from any angle. As the plot program uses parallel projection from the positive Z - AXIS, the object may be turned around all three main axes to get a view from a different angle.

A cross sectional plane may be specified at any Z - VALUE to break up the object and look at the interior. The cross sectional area is then hatched under 45 degrees.

There are several accuracy levels available. Thus, a test plot may be d upone with less accuracy to speed up the plot program.

The plot program uses a new algorithm, which is, to the best knowledge of the author, not yet described in the open literature. The basics of this algorithm is a special interpolation method. The main plot routines are only about 350 FORTRAN lines long. Therefore it may be of interest to realize this algorithm in hardware, as about 98 % of the plot time is consumed in those routines.

However, in using this special algorith it is not possible to plot hidden lines. In addition, the computer time rises approximatly linearly with the complexity., i.e. the number of volume elements.

Due to its power this algorithm is to be treated as trade secret of the author and therefore cannot be disclosed at this time.

8 Further Developments

There are a number of further developments planned. They all can use the description of the objects as described earlier.

8.1 Additional Volume Elements

Additional volume elements, which are defined by other surfaces as tori etc., can be added to the set of elementary volume elements.

8.2 Wire Models

It is possible to write a simple program to obtain a wire model of the object. Of course, this would produce only the cutting edges, not the outlines.

8.3 Macros

The data base is prepared to handle macro definition. That means that volume elements may be defined with variable dimensions. The actual dimensions are then specified by the use of the volume element.

8.4 Interactive Graphic Editor

In the near future an interactive graphic editor is planned which will enable the user to manipulate the object at a graphica terminal.

Further Developments

8.5 Automatic Dimensioning of the Object

The data structure of the data base allows the development of a program to automatically dimension the object.

8.6 Finite Elements

For the nearest future there is an interface planned for different finite element packages. The program is then able to generate the net automatically.

8.7 TV - Pictures

There is the possibility to write simple programs by using existing subroutines to create TV - pictures of the object, even in color. In addition it might be of intrest to generate pictures with several light sources to get different shadows. Of course the creation of films is then possible.

9 References

Literature:

- Th. Koehler, Rechnerunterstuetztes Maschinenzeichnen
  VDI - Zeitschrift 121(1979) Nr. 18 - September (II)

- Version 1 Reference Manual (German, unpublished)

- Version 2 Reference Manual (German, unpublished)

- Version 3.0 Reference Manual (available from the author)

Computer Mainframes, on which TECGRAPH is installed:

- CYBER 175
  Leibnitz Rechenzentrum Muenchen
  8000 Muenchen, West Germany
  Version 0 only until Jan. 1979

- PR1ME 300
  Lehrstuhl fuer Konstr. und Entwichlung
  im Maschinenbau der TU Muenchen
  o. Prof. Ehrlenspiel
  Luisenstr. 37a, 8000 Muenchen 2
  West Germany

- HP - 1000
  School of Mechanical Engineering
  Georgia Institute of Technology
  Atlanta, Georgia 30307, USA

- PR1ME 400
  School of Information and Computer
  Science
  Georgia Institute of Technology
  Atlanta, Georgia 30307, USA

- CYBER 74
  Office of Computer Service
  Georgia Institute of Technology
  Atlanta, Georgia 30307, USA

Contact Addresses:

- Th. Koehler, 469 Oakdale Rd NE #9, Atlanta, Georgia 30307, USA
- Th. Koehler, Zeisigstr. 30c, 8011 Vaterstetten, West Germany

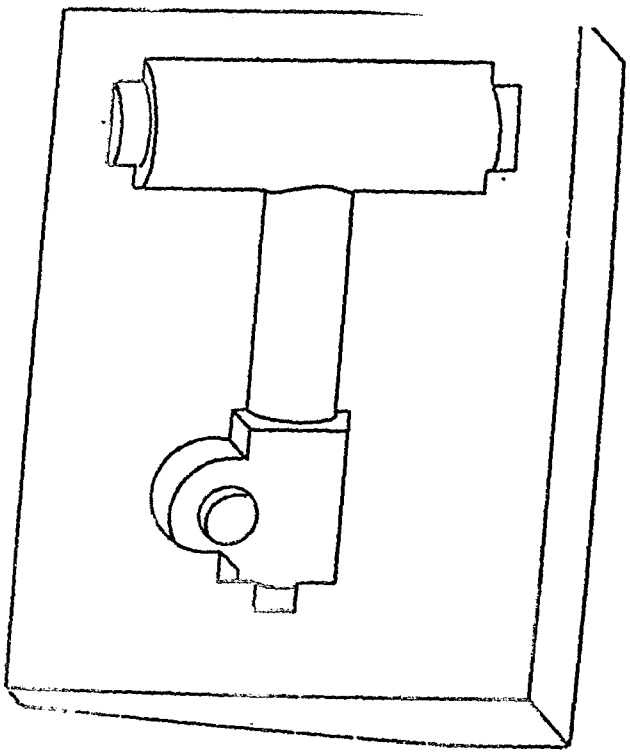
10 Examples

The following pages are to give a short survey of the multitude of different applications. All plots were done on a PRIME 300. The output is on a TEKTRONIX 4014 and then photographed. Each object consists of about 45 surfaces.

The first example shows a die casting (upper left). The mold is plotted on the right. The plot under the casting shows the mold and the cores.

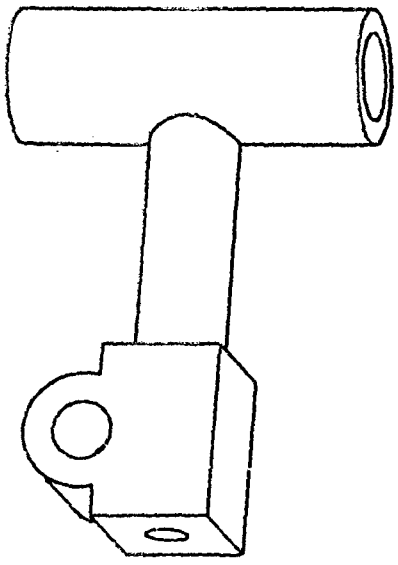
The next sample plot shows a cross section of a bush.

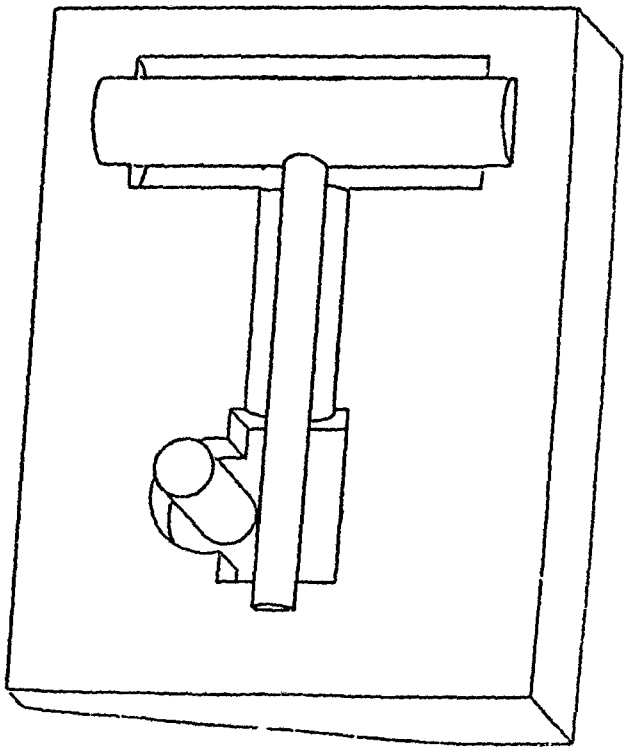
The last plot shows a model of an old steam engine. For this, a rough draft was used and the object was created only on the terminal.

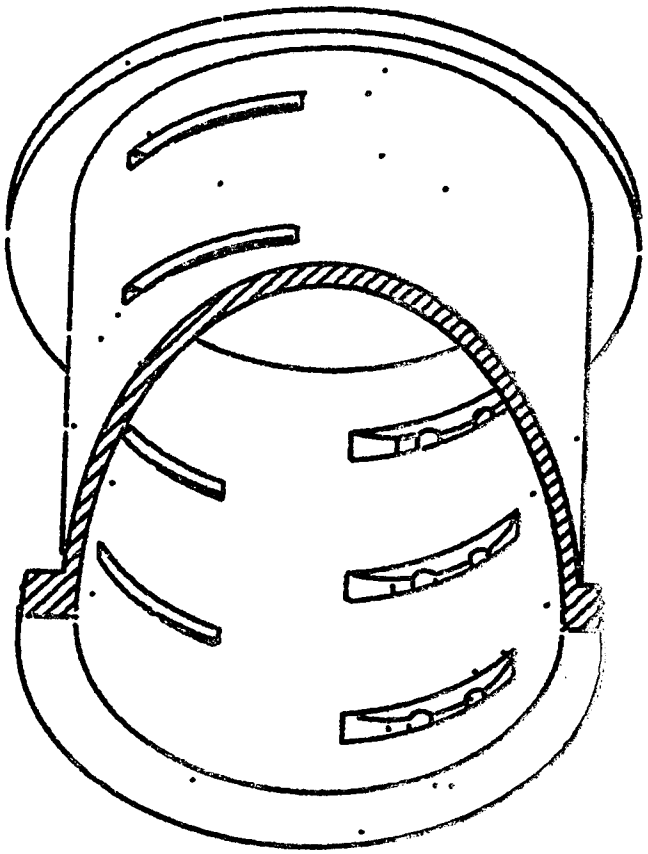


TECGRAPH TECHNISCHE COMPUTER GRAPHIKEN

EIN PROGRAMMPAKET ZUR RECHNERUNTERSTÜTZTEN KONSTRUIEREN VON TH. KOEHLER, UNTERSTETTEN

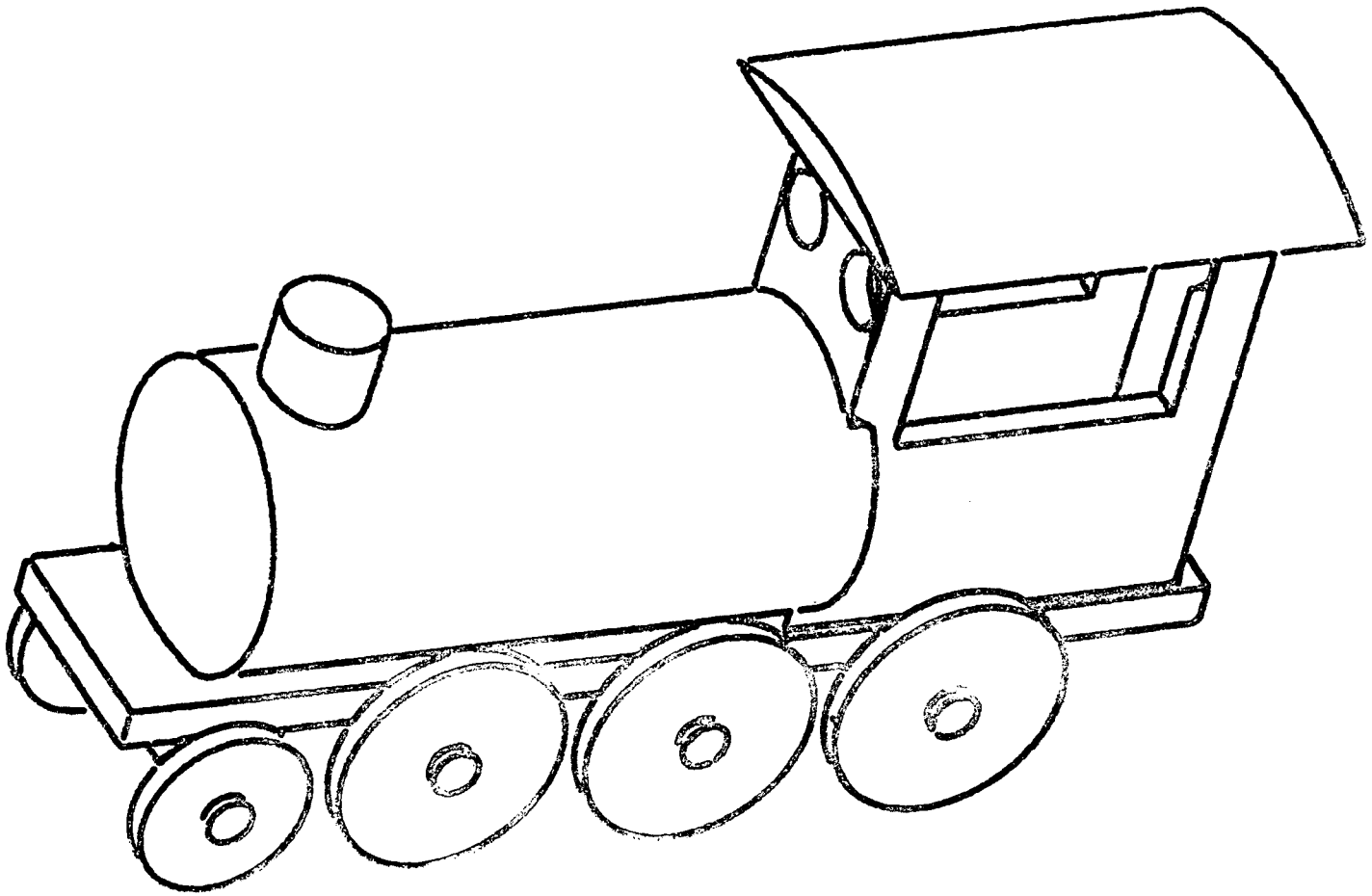






TECGRAPH TECHNISCHE COMPUTER GRAPHIKEN

EIN PROGRAMMPAKET ZUM RECHNERUNTERSTUETZTEN KONSTRUIEREN VON TH. KOEHLER, VATERSTETTEN



TECGRAPH TECHNISCHE COMPUTER GRAPHIKEN

EIN PROGRAMMPAKET ZUM RECHNERUNTERSTUETZTEN KONSTRUIEREN VON TH. KOEHLER, VATERSTETTEN