5-31-1991

Automated computer drafting of precision tooling for drawing operation

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ABSTRACT

Title of Thesis : *Automated Computer Drafting of Precision Tooling for Drawing Operations*

Venkateswarlu Basani, *Master of Science in Manufacturing Engineering, 1991*

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Based on customer requirements of components, design engineers create the necessary tooling using CAD to produce the exact part desired by the customer. A software package using CADL is developed to help the design engineer to create the drawings of Pinch off Punch and Pinch off for both rectangular/square and round punches. A variety of hole patterns for the punches are automatically created through the software, along with a possibility of selecting one of the standard patterns automatically for a drawing. The drawings are created such that the dimensions and the notes are automatically generated with the input of the punch length, height, width and other variables.

The Pinch off Punch and Pinch off are used to achieve high production. The required shape of the box or shell is formed over the pinch off Punch and is pinched to correct size with the Pinch off. The basic operation involved is drawing. Report presents detailed discussion on Pinching and Pinch trimming along with the discussion on drawing.

A brief outline of CADL, CADKEY Advanced Design Language, is presented to emphasize the capability of CADL to develop user interface from within the CADKEY environment, to automatically generate drawings, and to customize CADKEY operations.

2) AUTOMATED COMPUTER DRAFTING OF PRECISION TOOLING FOR DRAWING OPERATION

By

Basani Venkateswarlu

Thesis is submitted to the Graduate School of New Jersey Institute of Technology in the partial fulfillment of the requirements for the degree of Master of Science in Manufacturing Engineering.

1991

APPROVAL SHEET

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Automated Computer Drafting of Precision Tooling
for Drawing Operation

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ACKNOWLEDGEMENT

I have great pleasure in expressing my gratitude and grateful acknowledgements to Dr. Rajesh Dave, Assistant Professor, Mechanical Engineering Department for his valuable guidance and continued encouragement throughout this thesis work.

I am extremely thankful to Mr. John C. Loomis, Manager of Tooling Engineering, Hudson Tool & Die Company, Newark for his valuable suggestions and encouragement.

My special thanks to Dr. I. Fisher, Assistant Professor, Mechanical Engineering for his kind help in installation and problems associated with CADKEY software.

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INTRODUCTION

1.1 INTRODUCTION AND OBJECTIVE

Digital computers have brought considerable change to the engineering work place. According to Dewey[1] CAD systems are specialized according to the engineering function performed. CAD improves quality of work. Database features in professional CAD systems keep track of the effects of changes.

Computer aided design can be defined as any design activity that involves the effective use of the computer to create, modify, or document an engineering design. CAD is most commonly associated with the use of an interactive computer graphics system.

Computer aided manufacturing is defined as the effective use of computer technology in the planning, management, and control of manufacturing function.

CAD/CAM involves the use of digital computer to accomplish certain functions in design and production. CAD is concerned with the use of computer to support the design engineering function, and CAM is concerned with use of the computer to support manufacturing engineering activities. According to Groover[2] the combination of CAD and CAM in the term CAD/CAM is symbolic of efforts to integrate the design and manufacturing functions in a firm into a continuum of activities.

CAD can drastically reduce the number of steps involved in the design process for a particular product and can also make each design step easier and less tedious for the designer to perform. As a result, an enormous amount of time-saving can also be achieved between the initial conception of an idea and its final implementation as a product design. CAD enables an accurate representation of a design and provides the designer with a versatile tool to graphically manipulate it. The designer can easily obtain a deep insight into complex problems arising from the design. This will help the designer make better decisions and will reduce the possibility of having errors.

The objective of this thesis is to develop a software package to help the design engineer to design precision tooling for drawing operations based on customer requirement. The package is developed using the CADKEY and its programming language CADL.

The present work of the thesis is in collaboration with Hudson Tool and Die Company. It is the premier manufacturer of precision drawn metals, metal stampings and assemblies servicing the electronics, automotive, aerospace, hi-tech battery, and medical implant industries.

This company has complete capabilities to produce the tooling to support manufacturing operations.

The company uses CADKEY as the computer aided design and drafting package. At present they do not have the facility to automatically generate the drawings of pinch off punch and pinch off for the rectangular, square and round punches. They have to draw the drawings with all the dimensions and details on it for each drawing they make. This is a tedious and time consuming work.

A brief description of design of precision tooling is presented in the next section.

1.2 THE DESIGN OF PRECISION TOOLING

The design of precision tooling plays an important role in any manufacturing process. Production tooling is one of the most difficult of all industrial operations to standardize and evaluate for cost estimating. The fact that die building demands a high degree of accuracy, is seldom repetitive, rarely more than one of a design, requires highly skilled labor to perform the work involved; it is impossible to standardize enough of the work to assign elemental time factors. However, if we group the operations required to machine or assemble the die components, standard data factors and guides for construction can be used effectively.

Poor tool design and misapplication are major causes of premature failure. Tool design is closely related to tool steel selection. The die for the job must be designed so that it contains nonuniform sections, particularly a thin section adjacent to a heavy one. Most tool designers consider strength, toughness, wear and abrasion resistance, machinability and size change in specifying die steel. Hardenability should receive just as much consideration. Tools, such as pneumatic tools that are subject to severe impacts, should always be designed with tapered shanks. Many such tools are designed with heavy fillets at the changes in section. These tools most often fail at that point. Tools with tapered shanks seldom break because of fatigue.

The true meaning of tooling (jigs and fixture) software has been somewhat redefined, primarily due to major steps toward the integration of various computer software programs. In his paper, Duperret[3] has described about design of precision tooling. A theoretical, but possible, scenario involving a part as it goes from the concept stage to actual production will demonstrate the positive results being obtained with new tooling software packages.

Preliminary design sketches are prepared to determine the best possible design for the design of the tool required. Using these sketches, the engineer refines the design with the help of a CAD/CAM system. Drawing to full scale and utilizing the system's three-dimensional (3-D) capabilities, the tool takes shape as a "real" object inside the computer. When working in 3-D, the engineer is actually constructing a model of the part. It not only has length and width, but also depth.

The part design is finalized and the necessary design approval ackage is prepared for the presentation to the customer. This package contains 2-D engineering drawings and various 3-D renderings in both wireframe and solid-model images. Views of the finished part and all pertinent part specifications are produced from the single computer model.

With the system's multilayer capabilities, specific manufacturing step notes, dimensional notations, and material specifications will all be incorporated in the model. These various layers are like a conventional drafting board with 250 or more layers of paper all stacked together. To get specific drawing content, the designer would put together specific sheets of paper. To produce a solid-model image of the proposed part, the engineer can "turn off" or render invisible those layers that contain information not required at that point.

During the final design stages, the operations required to produce the part are to be determined.

After the customer has approved the design, the next step is to construct the fixture to hold the part in its raw form while it is being machined. The quickest method today to construct needed fixturing is to utilize a tooling library. Such libraries eliminate the need to spend hours drawing and fitting the various tooling components needed to hold the workpiece in a place properly. Accessing · OH the library, the engineer selects the specific tooling items and places them in the positions that seem appropriate. During this placement process, the layer that contains the part in its rough form is normally made visible. As a final check, the engineer turns off the rough part layer and turns on the finished part layer. This is normally done to ensure that the fixture's components have been placed so they will not interfere with any of the required machining positions.

Once satisfied with the tooling fixture, the engineer next generates an NC program to produce the customer's part. Making a combination of layers visible - namely, those that contain the rough part, the finished part, and the part's tooling fixture - the engineer calls on the system's NC program module to generate the machine tool instructions needed to produce the part. The various milling, drilling, and tapping locations are identified. Then the specific cutter information , drill and tap sizes, and the appropriate speed and feed information for each machine are entered. The program reviews all of the geometry contained in the computer model and generates the NC program.

The engineer is now ready to test the NC program for proper functionality. During this phase, the computer can simulate each of the machining steps, checking for such things as drilling depths, optimum machining operations, and possible fixture collisions. The engineer can actually create a finished part from itsrough form by having the computer perform the various machining operations. It is now possible to determine if there is going to be any workpiece deflection during a given operation. If there is, additional rest button can be added at the deflection points indicated by the simulation, or the feed rate can be reduced. During this process, it is also possible to identify any fixture design flaws.

If the customer's production volume is relatively high, the engineer wants to make sure the fixture is not underdesigned. An underdesigned fixture will always be adversely affected by the forces and dynamics involved during machining operations. Deficiencies may not become evident until 20 or 30 pieces have been machined. The engineer can simulate the entire production run and with the software tools now available, determine if all of the parts will be produced to the same dimensions and tolerances. The engineer will know, for example, that the round pins used as workpiece stops will not start to bend after 25 or 50 pieces.

1.3 OUTLINE OF THE THESIS

The outline of the thesis is as follows

Chapter two describes CAD and CAM, bridging the gap between them, CAD standard and how to improve the standard. It also describes and justifies CAD and CAM.

Chapter three describes the technical background about CADKEY Software, its programming language CADL, hardware setup for CADKEY and its applications.

Chapter four describes principles, theory, and stages of drawing operation. It also describes pinch trimming operation for which tools i.e. pinch off punch and pinch off the software package is developed to automatically generate the drawings.

In chapter five description is given regarding application of CADL for automatic generation of pinch off punch and pinch off drawings. It also describes the CADL elements, editing and running CADL programs. Example run for square pinch off punch is given step by step to automatically generate the drawing. The drawings automatically generated are shown in this section.

In chapter six concluding remarks and some suggestions are given. The CADL program listing is given in Appendix.

CHAPTER - 2

TECHNICAL BACKGROUND

2.1 CAD AND CAM

Computer-Aided Design/Computer-Aided Manufacturing by definition means dealing with the design, manufacturing and test phases of the product cycle[4]. Since physical products are universally represented by dimensioned drawings and associated textual attribute data, CAD/CAM applications must effectively handle both types of information in order to fulfill its objectives. Most design and manufacturing engineering application systems in production today originated before the advent of interactive computer-graphics hardware and software offerings.

Productivity improvement is the justification for CAD/CAM. Yet the measurement of productivity improvements from CAD/CAM are difficult to quantify. The commonly used term "Productivity Ratio" (PR) is a comparison of times required to do a given set of tasks the old way and the new CAD/CAM way.

The introduction of Integrated CAD/CAM systems requires careful examination of the impact that these systems have on traditional "ways of doing business". Required changes in the technical functions and administrative controls must be carefully developed with the participation and support of the organizations involved. It has been found that[5] the Boeing Aerospace Company has implemented Integrated CAD/CAM in a manner that has avoided many of the pitfalls common to other CAD/CAM implementations while producing measurable productivity improvements even in the early stages of implementation

According to Jorgen Jorgenson and Alting[6] Computer Integrated Manufacturing, CIM, is the ultimate goal for literally all types of manufacturing enterprises. The CIM concept includes highly automated manufacturing based on computer handled information flow, computer aided design and manufacturing activities, links to programmable and flexible manufacturing systems, and monitoring/control of all material flow and production activities.

Several of the individual systems and applications exist and can be fully utilized. CAD/CAM systems, for example, have shown major improvements in productivity and quality and possibilities with 3D Geometric Modeling and integrated analysis, visualization, drafting, creation of bill of materials and automatic programming of NC/CNC-machines. Although CIM is a long range goal and major problems concerning software and hardware linking, database structuring and management, special software refining (e.g. surface- and solid modeling software), manufacturing system simulation techniques, sensor system development, etc. still need to be solved, significant benefits can be reached in a step by step development of a computerized design and manufacturing system.

The essence of CAD/CAM, at any level, is the storage of information in a common database[7]. Traditionally, computer-aided manufacturing has been equated with creation of the code needed to drive automated equipment, particularly numerically controlled machine tools. So, linking CAD and CAM has commonly meant passing design information to the NC programming function.

In the computer-integrated manufacturing environment that most firms are working towards, however, CAM takes on a broader meaning. Some experts go so far as to say that CAM encompasses all computer-based manufacturing processes, which in today's factories means most activities. In this case, linking CAD to CAM means connecting design to numerous other departments and functions. As such, the link from CAD to CAM lies at the heart of CIM, but is a complex series of inter-relationships that are difficult at best to achieve[8].

In his paper, Koichi Ando[9] describes product design phase as the process to determine various attributes of a design object, necessary for the realization of functional requirements within the given design specification. These attributes usually include shape, dimension, material, weight, etc. The manufacturing preparation phase is the process to prepare the information necessary for operating manufacturing facilities. The design is a complicated intellectual process, and includes various kinds of decisions such as understanding the design specification, selection or creation of components, determination of connecting methods between them, supplement of detail shape and dimension to them, etc. Design for manufacturing is quickly becoming one of the most important trends in industry today. As the pressure mounts to bring new products to the marketplace as quickly as possible, the ability to reduce expensive modifications during the manufacturing phase by concentrating on the initial design has obvious benefits in terms of time and money saved. Design is the most important stage in the design-for-manufacturing process. A study[10] by British Aerospace found that the first five percent of resources, expended during the preliminary design phase, typically determines 85 percent of the final cost and performance of a product.

But no matter how useful such sophisticated tools as surface and solid modelers are in the rapid development of the best possible design, they count for nothing if the product can't be manufactured or assembled. Before design for manufacturing can become a reality, production and assembly information will have to be incorporated into the CAD/CAM database.

The manufacturing engineer is bound to ask whether the necessary machine tools are available and whether the designer's product can be assembled. If it cannot be made and assembled, it is not a product. The more the knowledge of production that is included in the CAD/CAM database, the more efficiently the product can be manufactured. For instance, a design should not specify a tolerance of 0.0001 inch if the available tools can only machine to a tolerance of 0.001 inch.

The incorporation of manufacturing information into the CAD/CAM database has several implications. One is that the database will have to deal with new types of information not only topology and geometry, but also form features, tolerances, and text, all in machine accessible format. Today information about a product is stored in several forms- in drawings and words, on paper, in computers, and in physical models. None of these forms represents the sum total of information about the product's design and manufacture. The CAD/CAM system will have to store a complete model in electronic form.

The ultimate goal of design for assembly is to have an expert system that, knowing the relationship between parts, can check designs to see if they can be made with fewer parts and can verify mating relationships automatically. Interactive finite element modeling and analysis techniques can greatly accelerate the creation and evaluation of design alternatives. Such analysis tools can predict how design in development will stand up to ensure that the manufactured product performs correctly and that time is not wasted on a product that will eventually be discarded.

Finally, simultaneous engineering will go a long way towards furthering design for manufacturing. Its two underlying concepts are parallel development of the product and the manufacturing process, and the creation and evaluation of multiple product and process design alternatives. Simultaneous engineering gives manufacturing and design engineers a real opportunity to determine in advance, by working together, the least expensive way of manufacturing a product.

Although design and manufacturing are coming closer together, the two will never merge. Both will continue to be specialities requiring specific tools, but in the future they will be linked. With simultaneous engineering, each participant will exercise authority in his or her own area of specialization, but all will use the same data base. This common data base will ensure that separate jobs are done with reference to each other. Design is a world of creativity and experimentation. Manufacturing is a world of rigor, in which the concerns are quantity, time, and prices. Simultaneous engineering, acts as a valve between the two.

The first step toward linking CAD And CAM is to ensure that designs include sufficient data to automate manufacturing[8]. One available solution is solid modeling, which can represent the unambiguous data needed for manufacturing. For a solid modeler to assist in this link, however, it must be an integral part of the design-Hsystem instead of merely a way to create nice-looking graphics. Companies must treat solids modeling as a core application. Of course, the solid models must also accurately represent geometry to be used for manufacturing.

Several CAD/CAM vendors are re-doing their approach to modeling to include more design information data for manufacturing purposes, thus strengthening the link between CAD and CAM. A prime example is Intergraph, which has recently introduced its Engineering Modeling System (EMS) based on object-oriented programming techniques. This approach allows relationships between objects to be included with the geometry.

NC programming is then layered on top of EMS, and the geometry of EMS is associated with the tool path geometry. Initially, such an approach will allow easier generation of NC tool paths. But the basic structure of EMS will eventually mean ·hat whole NC programs will not have to be regenerated after a design change. Localized changes to the NC program will be able to be made without recreating the entire program. Ultimately, the system will return information about the manufacturing process to designers. Another way of adding more information to a design to ease NC programming is by form features. Form features are most often associated with solid modeling, allowing users to define geometry by machining-like commands instead of solid modeling lingo needed for to perform Boolean operations. The resulting model would then contain much of the information needed to create an NC program.

Strengthening the connections between present-day CAD systems and NC is a necessity when the two systems are supplied by two different vendors. The problem is essentially two fold: there must be a physical communications link and a common format for the data.

The communications link is considered to be more of a hardware problem than something that must be addressed by software writers. A simple way to make the connection is through a standard tape or floppy disk. A more sophisticated approach is to link the CAD system to the NC system through a network. This technique is becoming popular as engineering workstations, adept at networking, proliferate.

The data link is more complex. In some systems, CAD and CAM are joined through a common database. Linking CAD and CAM means a common database for both design and manufacturing. The CAD/CAM database is the key element in integrated design and manufacturing systems [11]. Its proper usage can reduce product design time to a third of that normally required. In some instances, CAD/CAM has shrunk design time by a factor of 20.

A common database is not always attainable, however, so interfaces must be used instead. Users would like a standard to solve the problem, which is one reason why the Initial Graphics Exchange Specification (IGES), a standard way to format CAD data, was created. Most problems with IGES transfers involve items such as text rather than the x, y, and z data needed for manufacturing. According to Robert B. Mills[8] IGES does a good job at reducing re-entry of data and maintaining the dimensional integrity of a design.

In addition to IGES, there are numerous other ways to pass CAD data to NC. Some vendors of NC software make direct interfaces to popular CAD systems. Binary transfer of data (without going to an intermediate file such as IGES) will be the wave of the future.

The link between CAD and CAM also needs to be a two way street, according to some experts. They say that designs sometimes get altered for machining purposes, so this information must be passed back to the CAD system for designers to use. Point control's CAM connection software, a translation program that connects CAD systems to the firm's NC programming package, allows this bi-directional flow of data. Although the problem of getting part geometry from CAD to NC is being solved, the interface looks to become more difficult as CAD vendors work to add "intelligence" to their data. One solution is already in the works: the Product Data Exchange Standard (PDES) is being touted as the next step beyond IGES. PDES reportedly will include a more intelligent description of a part than just geometry.

Other efforts focus on improving the link between CAD and CAM by making NC programming software "smarter." Although experts say that someday NC programming might be done entirely by software, such capability may be beyond today's technology and is not even desired by most firms. NC programming languages such as APT or Compact II are still popular but are generally used in stand-alone applications where programmers work off blueprints. Today, however, the more advanced NC systems allow users to work in graphics rather than a language. These systems greatly ease the task by permuting programmers to visualize tool paths. Such systems are considered to be essential to put NC on an equal footing with CAD. Some CAD/CAM vendors are steering clear of taking the next step to automate NC entirely from CAD data.

One hurdle that must be overcome to linking NC to CAD is the dichotomy between complex machining and simple machining. Geometrically complex machining is a natural for CAD/CAM , thus facilitating a link between design and manufacturing. For simpler machining, however, many companies turn to low-cost systems.

In summary, the basic concept of CAD/CAM is that individual functions in design and manufacturing are computerized, and that these functions are tied together through a central computer database shared among them. As a result, a CAD system allows a user to interact with a computer through a graphics terminal to define a design configuration, analyze the structure and its mechanical behavior, perform kinematic study and model testing, and automatically produce engineering drawings. Then the production people can make use of the geometric description provided by CAD as a starting point in CAM to create NC programs for machine tools, determine process plans for fabricating the complete assembly, instruct robots to handle tools and work pieces, and schedule plant operation with a factory management systems. Furthermore, the able use of CAD/CAM facilities should be instrumental in reducing the levels of supervision prevailing in an organization

The above fig. 2.1 shows an idealist structure of a CAD/CAM system. Many existing CAD/CAM systems available in the market already have all the CAD functions integrated and even have full NC capabilities. However, the other CAM functions are still in different stages of development and are usually performed independently of the CAD/CAM system. From fig 2.1. it can be seen that CAD features consist of geometric modeling, analysis, testing and drafting, where as CAM functions include numerical control, robotics and factory management.

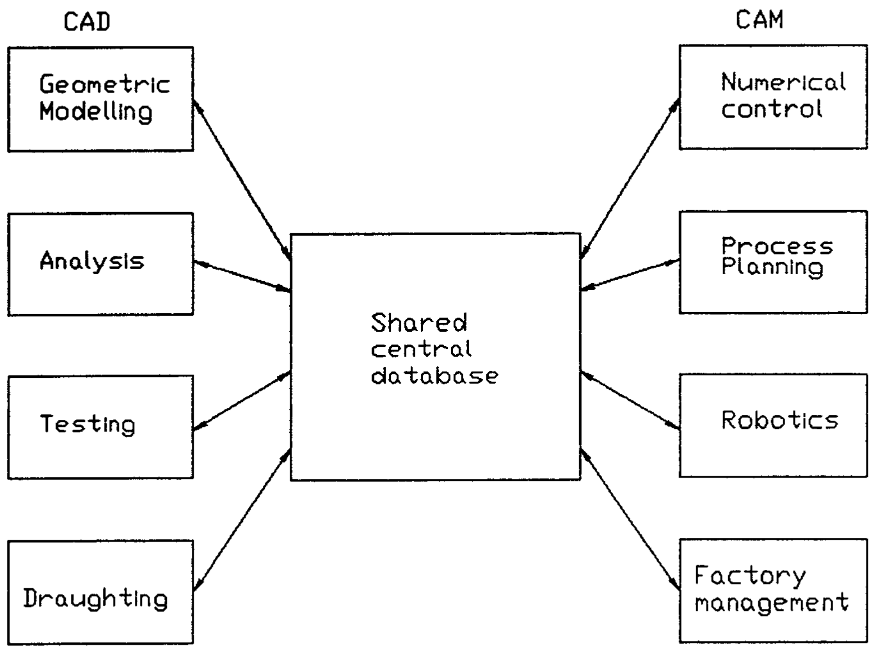


Fig. 2.1 - The concept of integrated computer-aided design and computer-aided manufacture (CAD/CAM).

2.2 BRIDGING THE GAP BETWEEN CAD AND CAM

A major reason why linking CAD and CAM systems has been so difficult to achieve with a single data base is that electronic and mechanical designers know so little about each other's work. Traditionally, CAD/CAM system manufacturers have tended to be electronics designers, who are able to build unified CAD data bases but are unfamiliar with manufacturing operations.

Another problem is that manufacturing information is more complex than design information, and more difficult to codify in a data base. For example, in a CAD data base, geometric descriptions of a part and information as to its assembly are the only data needed. A CAM data base, on the other hand, must contain information on processing the part, the cutting tools to be used, the cutting tool paths, inspection-tool paths, off-set geometries, and geometries of the fixtures used to produce and test the part[12].

To complicate the problem, information obtained from a CAD data base will often need to be modified for CAM operations, and the modification may go unnoticed by the part's designers. The reverse situation, in which the designer modifies the manufacturing data, can also occur.

Many systems that claim to be suited to both CAD and CAM actually handle more design than manufacturing functions. Although they can generate tool-path programs to drive NC machines and machine tools, their manufacturing capacities are limited. They can not control dimensional accuracy to the sixth or eighth decimal place, a level of precision essential to manufacturing parts with complicated shapes and contours.

It is only in the electronics industry that CAD is truly linked to CAM for the manufacture of integrated circuits and printed-circuit-boards. In this relatively simple process, the finished design of an IC or PC board is photo plot art work, which becomes the tooling with which the electronic part is manufactured. The same process is not applicable to mechanical engineering, in which the drawing of a mechanical design is insufficient as a manufacturing tool. The design data base for such a part may be complete and accurate, but it lacks the continuity necessary to be transferred to a manufacturing data base. In a handful of cases[12], more the exception than the rule, integrated CAD/CAM software has been successfully written and used to manufacture complex mechanical parts. One such program is Euklid/Ozelot, an integrated system for the design and milling of complex molds, dies, and other shapes. It was developed a few years ago by the Fidos Trust Company, in conjunction with the Institute of Machine Tool Technology of the Swiss Federal Institute of Technology, Switzerland.

There is a particular need in mechanical designs for CAD and CAM model generators that better represent their respective operations. While two-dimensional images have proven sufficient for much CAD work, they are not enough for CAM, which requires three-dimensional manipulation and viewing of objects.

For these and other reasons, proponents of separate data-base systems have favored keeping each data-base function within its own discipline - a manufacturing data base in manufacturing , a design data base in engineering. The use of software translators to communicate among data bases could overcome the incompatibility problem; and local-area networks like Ethernet can be used to transfer large amounts of information in burst between one data base and another.

The large volume of data involved in linking CAD and CAM, which often forces the most advanced systems to operate at or near their limits, represents a major stumbling block to the use of a single data base. Managing these data is extremely difficult because of the limits of on-line storage for CAD/CAM systems. Most CAD/CAM systems have about one gigabyte of on-line storage capacity, enough to store information on about 300 parts. But many companies typically have several hundreds or even thousands of parts on their systems, so the overflow information must be stored off line. If these overflow data are separated into respective data bases, memory management becomes less difficult. The use of relational data-base management systems may improve this situation. These systems free the user from dependence on storage structures, making accesss to the data base simpler and more efficient.

In a relational data base system, data manipulation is conducted through operations that produce new relations. For example, by combining tables and arbitrarily selecting rows and columns, users can create new relations for display, processing, or storage in one operation. Relational data-base management systems are replacing older hierarchical and network data-base management systems.

As CAD/CAM moves out of drafting departments and into other areas of design and manufacturing, the need for data-base management grows. A die designer , for example, might draw information from design and drafting files to develop the die, then transfer that information to a machining program. Without adequate data-base management, it is nearly impossible to ensure accurate information in all phases of the design process. Data-base management systems integrate data from different files so that inconsistencies and inefficiencies from duplicated data do not arise. Group technology software is being used to join elements of CAD and CAM , providing smoother data-base management and reduced manufacturing costs.

The problem of CAD/CAM interfacing is complicated by the difficulty of connecting CAD and CAM systems of different manufacturers. No two systems speak the same CAD, much less CAM, language.

2.3 CAD STANDARD

The Initial Graphics Exchange Specification (IGES) is a standard data format[13] for product design and manufacturing information created and stored in a CAD/CAM system in digital form, and is designed in such a way that it is independent of all CAD/CAM systems so that geometric and manufacturing data can be readily transferred between different systems.

IGES format can be used to describe drafting and geometric entities such as :

(a) Geometric - point, line, arc, spline, etc.

(b) Annotation- dimensions, drawing notes, etc.

(c) Structure - properties, associations, groups, etc.

The transfer of data between CAD/CAM systems using IGES format requires two separate stages as illustrated in fig. 2.2. For example, if data are to be sent from system A to system B, they must first be translated into IGES format by using preprocessor in system A. Then, the resulting IGES entities are translated into the internal format of system B by its own IGES post processor. If data are to be transferred in the opposite direction , that is , from system B to system A, the process involved is essentially similar except that the IGES preprocessor of system B is used to convert its data into IGES format which is subsequently converted into system A data by its IGES post processor.

IGES is a data format for describing product design and manufacturing information which has been created and stored in a CAD/CAM in computer-readable form. The IGES is the public domain and is designed to be independent of all CAD/CAM systems[14].

The benefit of this common format is that a user does not have to develop special translators for each different piece of equipment that is used. The only requirement is to have a translator to and from the IGES format. These translators, called pre-and-post processors, are generally available from the equipment vendor. In addition, an IGES file can be stored on magnetic tape or disk memory for future use. It can also be transmitted between systems via telecommunications.

To stem the proliferation of software translators, the Initial Graphics Exchange Specification (IGES) was developed by a joint government/industry committee that includes the National Bureau of Standards. IGES is a neutral data format that describes product design and manufacturing information for different CAD/CAM systems[12]. It is a data standard for

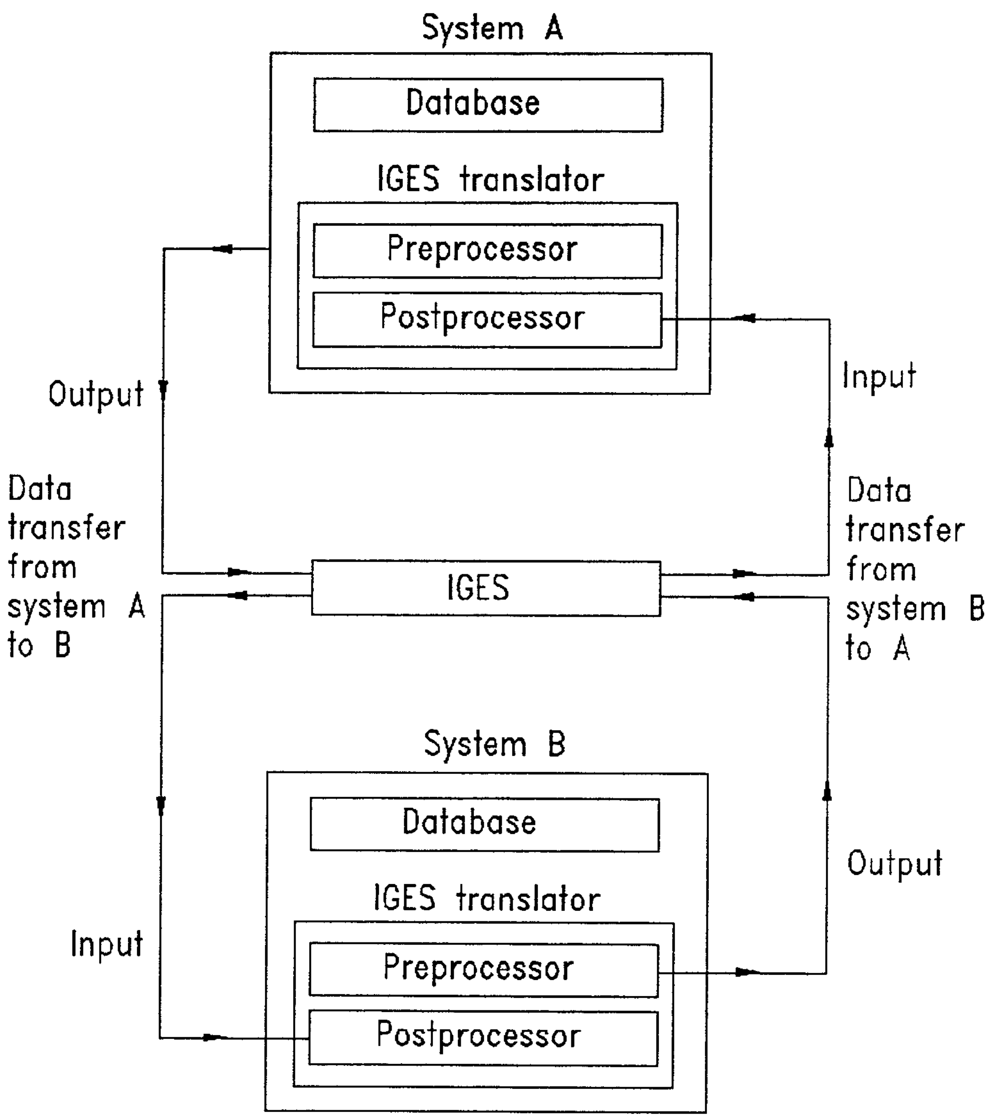


Fig. 2.2 Data transfer between CAD/CAM systems

communicating geometric product information among computers. In its present format, IGES handles more design than manufacturing information; however, the newest version (3.0) is being improved so it can handle more advanced CAM1OH information.

Almost all CAD/CAM system vendors claim to support IGES and consider it a valuable step toward a CAD and CAM link. But it has also been pointed out that while many CAD/CAM manufacturers applaud IGES in theory, they continue to keep their data bases as inaccessible as possible so as to retain their customers. Just as many CAD/CAM systems still rely on translators as use IGES. For IGES to be useful, it must be a superset of all existing CAD data bases. Still, IGES is a step in the right direction. For four CAD/CAM systems, only eight translators are needed when IGES is used, as opposed to the twelve direct, system-to-system translators that would be required. The difference becomes even more impressive as the number of CAD/CAM systems increases, since the number of translators required increases dramatically without IGES; with it, the number of translators is only twice the number of systems.

Another benefit of IGES is that the CAD/CAM system manufacturer, rather than the user, writes the IGES software translators. This ensures better intersystem compatibility, since the manufacturer is more familiar with his system than is the user.

IGES is not without it problems. Critics have argued that as it has grown to serve a wide variety of users it has become too flexible in its ability to represent the product data. This can make IGES confusing to use and could possibly cause data loss. Indeed, IGES is most successful when handling simple, two & three dimensional CAD drawings. More complex drawings involving splines, curved surfaces and annotations are difficult to achieve with IGES. IGES is limited to handling three-dimensional wireframe drawings; it cannot produce solids-modeling representations, nor can it support more than a limited number of rotations.

There are some other, more practical problems. For one thing, many CAD and CAM data files cannot be converted through IGES. For another, not all IGES versions (2.0, 2.2 & 3.0) are necessarily totally compatible with one another. Again, this is due to the proprietary data-base schemes CAD/CAM vendors use in their products.

Yet the need to tie CAD and CAM systems together is indisputable. Advanced NC techniques using lasers, water jets, and electromechanical systems for material-cuttings are increasing the need for CAD/CAM systems that can generate information on more complex parts.

2.4 IMPROVING IGES

The Enhanced Specification Proposal (ESP), is an experimental solids-modeling standard that may make IGES more useful. Developers of commercially available CAD/CAM software packages like Prism/DDM from GE's Calma Division have embraced the idea of ESP. The solids-modeling Prism/DDM is an upgraded version of Calma's wire-frame-modeling DDM software package for mechanical designs[10]. While many CAD systems must first download part-cutting instructions into a computer that converts them into instructions the NC machine tool understands, Prism/DDM allows the generation of NC tapes directly from parts geometry information in its data base.

A major limitation of IGES is that it does not cover such non-geometric data as tolerances, which are also part of a complete product description. The National Bureau of Standards has recently proposed a Product Data Exchange Specification (PDES). PDES creates data files that can be interpreted directly by advanced CIM systems.

Despite its problems IGES represents a vast improvement over any other technique available for linking different design and manufacturing data bases among different CAD/CAM systems. As CAD/-CAM system vendors begin to use IGES more, the system is bound to be improved, and perhaps it will lead to the hitherto unattained single and unified CAD/CAM data base for the factory of the future.

2.5 JUSTIFYING CAD/CAM

The benefits of CAD/CAM are tremendous, and the competitive need is urgent. The obvious benefit, of course, is reduced engineering costs[15]. But the advantages of CAD/CAM go far beyond that. Some benefits to consider when justifying a system:

* Shorter product design cycles free up engineering time for other projects.

* Warranty service costs are reduced, thanks to improved quality.

* Fewer prototypes lower the cost of construction and testing mock-ups. In some cases, prototypes can be completely eliminated.

* Better communication between design and manufacturing reduces redesigns and complicated production methods.

* Making the design right the first time results in fewer engineering change orders. And, the ones that still have to be done can be implemented more efficiently.

CHAPTER - 3

3.1 CADKEY AND CADL

CADKEY is a microcomputer-based 3D Computer Aided Design software Package which functions as a complete design and drafting tool. A brief introduction of its features and capabilities are presented in this chapter. Detailed information can be found in [16].

The combination of a unique human interface and a rich assortment of functions offers the occasional or experienced user an opportunity to build upon ones own expertise in a step-wise fashion, using a variety of options and techniques, including macros and CADL.

CADKEY pays off handsomely in saving time and preserving intellectual energy by relieving the designer of the tedious chores associated with drawing and converting a 3D concept into a 2D image. Drawings are generated quickly and efficiently in both a 2D and/or 3D perspective. With 3D capabilities, editing becomes a one-step task. Rather than having to laboriously change each view of a drawing, one modification is applied to all views. Parts as whole are created and managed .

CADKEY's command menus are robust and organized in a logical manner, and using a mouse with the program is as easy as using a digitizing tablet. Each time it prompts the user to pick a point on the screen. CADKEY displays a snap menu that lets the user designate the snapping mode; the user does not have to go to a separate menu. All drawing commands are inherently 3-D [17]. keystroke macros can be recorded and complex tasks can be automated with the built-in CADL programming language. CADKEY'S emphasis on economizing keystrokes results in reduced drawing time.

The CADKEY screen can be split into up to 16 viewports; views can be chosen from eight predefined views (six orthogonal, one isometric, and one axonometric) or created by rotating the part through any angle around any axis in 3-D space. Drawing operations can be performed in any of the displayed views and can even span viewport boundaries. CADKEY fully supports instancing, in which one can build a single 3-D model of a part and derive as many 2-D orthogonal views from it as needed. Creating the mechanical drawing requires generating a 3-D model, taking snapshots of it (called pattern files in CADKEY parlance) from three different directions, and reading the pattern files into a blank drawing. Once there, objects imported through pattern files can be edited and dimensioned just like objects creating from scratch.

CADKEY Solids is more than just a rendering package. In addition to lending wireframe models more visual appeal by removing hidden lines and shading surfaces, it also calculates properties such as volumes, centers of mass, and moments of inertia. But perhaps more significant is the way it creates them. Rather than leaving us to surface models by hand, CADKEY Solids will generate surfaced models directly from your wireframe geometry.

According to CADKEY INC. CADKEY is superb both as a 2-D drafting system and as a 3-D modeler, and it offers most of the features of Auto-CAD and Auto-Shade for a little more than the price of Auto-CAD alone.

3.2 CADKEY STANDARD FEATURES

The power and flexibility of multiple viewports:

* Automatic and manual viewpoint placement and sizing (up to 16 at once).

* 3-D display view and construction view axis in all viewports.

* Grid and snap available in all viewports.

* Totally associative 3-D cursor interaction in all viewports. One can draw in one view, connect to another, and view the design in several different viewports at the same time.

* Pop-up menus in selected functions allow for more direct access to levels and files (in short or long form), plus group table and color table.

* CADL (CADKEY Advanced Design Language) and macro capabilities.

* Plotting and Printing in selected viewports.

* completely open database for easy access to external manufacturing programs.

* Standard cartesian coordinate system (x,y,z).

* Simple menu structure, allowing you to input design steps in logical sequence.

* Continuous History Line of the commands one choses within a function.

* Eight pre-defined views (top, front, back, bottom, right, left, isometric, axonometric), along with an unlimited number of views you define.

* Efficient selection routines such as: single select, window, chain, grouping, plane definition or all displayed- with masking by entity, level, or attribute.

* A UniversalPosition Menu with virtuallyunlimitedmethodsfor indicating a position (or location) in 3-D space.

* Instant access to key functions from anywhere in the menu structure via unique Immediate Mode commands or the interactive Status Window.

* 256 Levels (layers) of construction.

* 256 colors.

* Continuous tracking of cursor location (x,y position and depth).

* Ability to update and edit menu/prompt files.

* On line calculator which supports many trigonometric and algebraic functions, as well as the ability to use variables.

* Compliance to ANSI, ISO, BSO and DIN standards.

3.3 HARDWARE SETUP FOR CADKEY

REQUIRED HARDWARE

a) PC BASED SETUP

CADKEY runs on IBM PC/AT, or other IBM compatibles under MS DOS or extended MS DOS 386. CADKEY supports a wide variety of the most popular graphics cards, input devices, printers and plotters.

b) WORKSTATION BASED SETUP

CADKEY runs on Silicon Graphics Personal Iris, Sun SPARC stations, DG Aviion 300, and Sony News (with CISC processor).

3.4 APPLICATIONS

The applications of this system are limited only to the resourcefulness of the user. Some common tasks performed within the system are:

- Mechanical Design/Drafting

- Architectural Design
- Engineering Analysis
- Medical Analysis
- Graphic Presentation
- Technical Publications
- Computer-Aided Machining
- 3D Digitizing (inspection)

The CADKEY Advanced Design Language (CADL) is a powerful programming language which operates within the structure of the CADKEY program. The flexibility of this language allows us to design and store our own functions and entities within CADKEY, as well as access the CADKEY database[18]. A programming language is needed because CAD systems cannot be perfectly suited to every application. CADL is a powerful tool because it

- can draw the same entities that CADKEY can
- can access entities that already exist
- adds programming abilities, such as

    * file and device input/output
    * conditional branching
    * interaction with user

Some of the more common applications of CADL are:

- Parametric Programs: These are programs that will draw an object (a bolt, for instance), simply by the user providing parameters such as length, diameter, and thread size.

- Customization: Although CADKEY provides many functions, it cannot have every function one requires. One can add commands not found in CADKEY that might use routinely, such as printing out a list of all the levels we have used, or drawing a cube.

- Data Transfer: Other programs often have a use for the data in a CADKEY part, and vice-versa. CADL provides an easy way to provide, and access data in the correct format for each program.

In order to use the CADKEY software one needs the following:

- A text editor such as VI, BRIEF, or a word processor in the non-document (ASCII) mode.

- A computer that has the CADKEY program installed on it.

- A familiarity with the CADKEY program.

CHAPTER 4

PRINCIPLES OF DRAWING OPERATION

A large variety of operations can be performed on a single press set ut with the proper dies. The tools used, punches and dies, work together as a unit. The punch is attached to the ram (slide) of the press and, in operation, is forced into the die cavity.

4.1 PINCH TRIMMING.

High production is achieved by combining blanking from a strip with drawing and trimming operations. A blanking punch blanks and draws the shell over the plug, and the shell is pinch-trimmed by a pinch in the lower member. A knockout ejects the shell at the top of the stroke, and a spring stripper removes the strip from the blanking punch. The pressure pad supplies pressure for drawing and strips the scrap ring from the trimming punch.

A pinch trim can be incorporated with a standard drawing or reducing operation, eliminating a separate operation. Clearances between the punch and die must be held to a minimum so pinch off is even and the formation of sharp or rough edges on the part is prevented. Figures 4.1 and 4.2 show a die in which drawing and pinch trimming are combined. Pinch trimming may also be done in a push-through die. In this type of die the sharp cutting edge of the punch trims the shell flange against the radius on the die opening, where there is some ironing action. The shell is pushed entirely through the die.

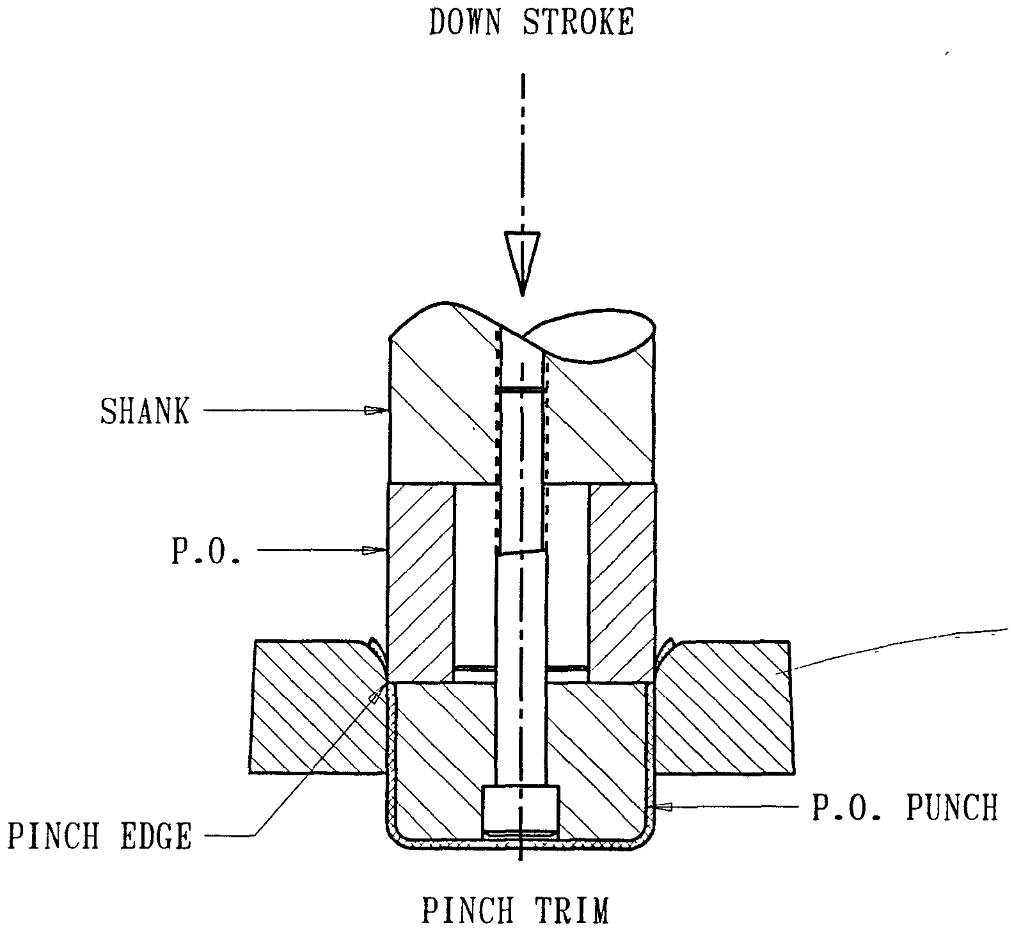


Fig. 4.1 Pinch Trimming - down stroke.

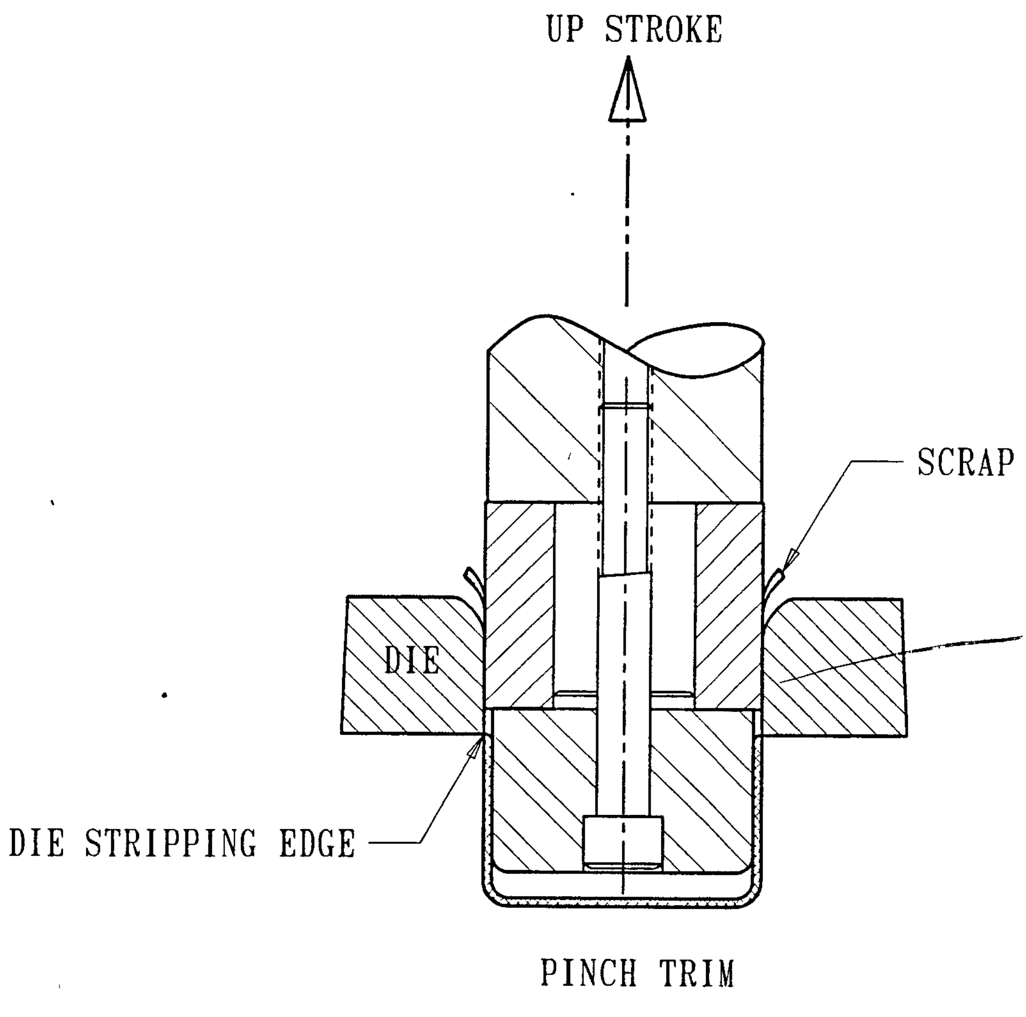


Fig. 4.2 Pinch Trimming - up stroke.

Figures show a simple type of draw die pinch off punch and pinch off in which the precut blank is placed in the recess on top of the die, and the punch descends, pinching the cup through the die. As the punch ascends, the edge of the shell expands slightly to make this possible. When the punch comes in contact with the stock, it will be drawn into the die without allowing wrinkles to form.

4.2 DRAWING

A process in which a punch causes flat metal to flow into a die cavity to assume the shape of a seamless hollow vessel[19]. Drawing operation as shown in fig. 4.3 consists of pressing or stretching a flat blank or sheet over a die having the interior shape of the workpiece to be produced[20]. Since the perimeter of the blank is greater than the part to be drawn, its reduction - as the metal is forced through the die opening - sets up a higher compressive stress, which has a tendency either to thicken or buckle the blank.

4.3 THE THEORY OF DRAWING

The typical drawing operation begins with an appropriately sized flat blank. The blank is then subsequently formed into a cup as the metal is progressively pushed by the punch over the draw ring. The area of the developed blank before drawing should be the same as the surface area of the shell after drawing, providing the thickness of the material remains unchanged [21].

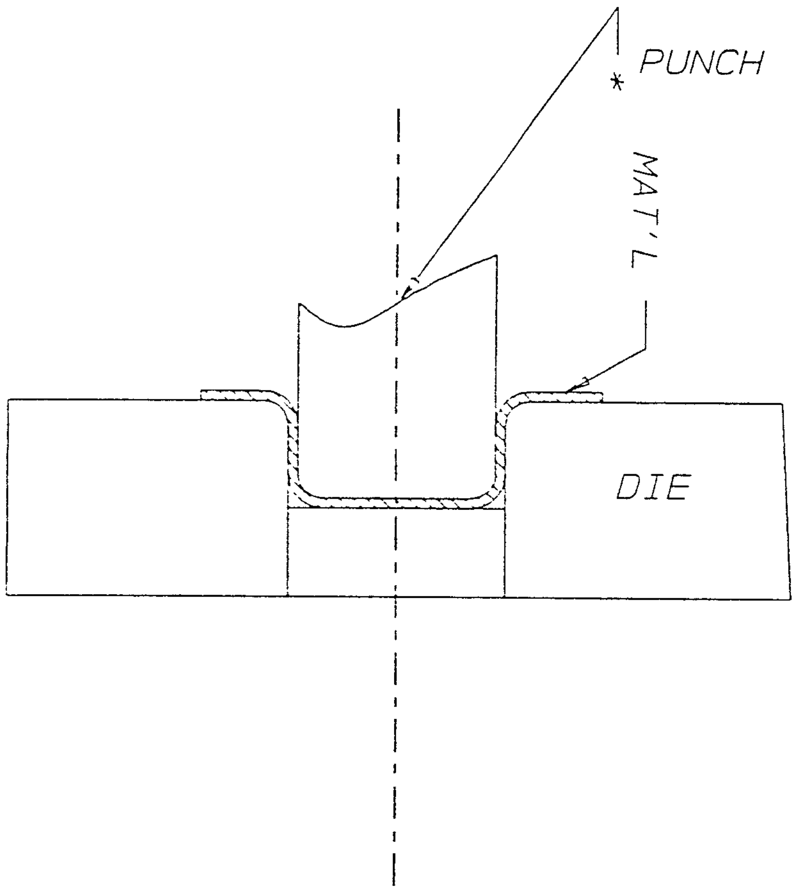


Fig. 4.3 Drawing Operation.

As the metal is pushed through the die opening over a radius, the drawing action causes the shell to hug the punch. This requires a stripping action. The pressure pad exerts a force on the " lip " of the partially drawn shell. This force holds the lip down with a pressure just enough to permit the material to slide out from underneath once the punch starts to descend. Under this kind of action, the metal must flow over the die radius without flapping up.

If the metal lips on the partially drawn shell were permitted to flap up, a larger circumference of material would try to crowd into the smaller die opening circumference. Folding would take place at the die radius. As the punch continued down, these folds would be too thick to pass through the punch and die clearance. The folds would be " ironed " out and appear on the finished product as wrinkles.

If the metal lips are held too tightly, the punch would either tear the bottom out of the shell, or stretch the material in the walls of the shell. If the radii are too small, breaks will occur near the punch radius or soon after the material enters the die opening. As a general rule for sheet metal the radius over the die ring should be about four times the thickness of the material. The punch radius should be at least the same size as or larger than the radius in the die ring. Since the material is pulled over the die - ring radius, friction is a factor which must be considered. The die - ring radius must be highly polished and lapped. This will reduce the tensile forces on the shell and will eliminate the possibility of the radius picking up metal from the shell walls, which will cause scratches in the sides of the shell.

It is also possible to reduce the wall thickness of shells by controlling the clearance between the punch and the die. As s general rule wall thickness for ductile materials may be reduced by 10% of the original thickness of the material. Other factors such as the type of material, the ductility, and the work hardness which takes place during the operation must be considered.

There are three types of drawing methods: (1) Single-action, (2) Double-action, and (3) Triple-action.

Single-action presses draw blanks of sufficient thickness so that the flange or wall will thicken rather than wrinkle when drawn. Brake drums, cartridge components, and gas containers are made by this method. Additional draws may be made on a cup-shaped part, with dies that reduce shell diameter and also control wall thickness.

Double-action drawing is the most common form of drawing and involves the shaping of thin sheets. An outer member, or blank holder, keeps the sheet flat to prevent wrinkling, while a drawing punch forces the sheet into the die against the draw ring of the blank holder.

Deep draws are usually accomplished by a double-action press fitted with a blank holder slide with a dwell motion and a is driven and guided within the blank holder.

Hydraulic presses are also made with double action to produce deep drawn parts. This type of press is suitable because of its slow action, speed control, and a pressure that is uniform.

Some stampings in automobile plants are made on triple-action presses, automobile doors for example. The blank holder produces the flange and a draw punch draws the edges and shapes the door while a lower slide rises and forms the window opening.

4.4 STAGES OF DRAWING

Of the stamping operations, drawing certainly involves the greatest variety of variables[22]. It is necessary to identify these variables as they exist during the operation. Even before this, the general metal flow patterns, as the die closes, must be reviewed.

The stages or steps of drawing flat-bottomed cups is presented in fig. 4.4. The sectional view in fig. 4.4.1 shows the punch at the instant of contact with the flat round blank.

a) BENDING. As the punch lowers into the die opening, several distinct phenomena occur. At this first instant of punch movement, sheet metal is bent to the punch radius, as shown in fig. 4.4.2. Likewise, adjacent metal is bent over the die radius. The flat metal in contact with the punch face is moved downward. Thus the bottom of the cup is in final form. This flat bottom is not work hardened and the

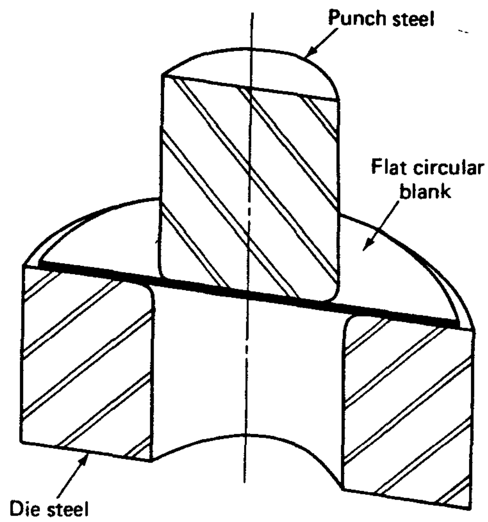


Fig. 4.4.1 Initial Contact With Blank.

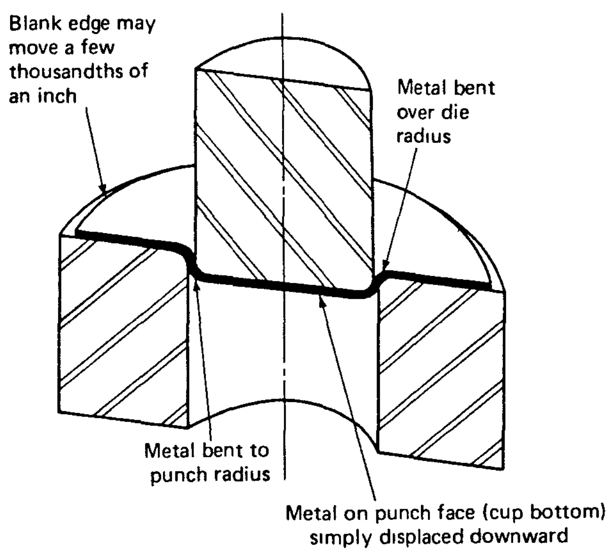


Fig. 4.4.2 Bending at Start of Operation.

Fig. 4.4 Stages of Drawing.

sheet retains its original thickness in this area. At this stage of drawing, the operation is actually no more than simple bending or forming. Similar metal shaping could have been done in a solid form die. The real draw action has not begun as yet.

It is logical to expect bending to occur first, since bending forces are very small compared to the force needed to compress metal as it flows toward the die radius.

b) STRAIGHTENING. Next consider that the punch has moved down another small portion of its total travel. At this stage, the flat cup bottom is simply moved further down, as shown in fig. 4.4.3. The metal bent to the punch radius is also being moved with the flat bottom. An entirely new situation has been created at this point. The metal previously bent over the die radius has been straightened. Additional sheet metal is being bent over the die radius. An unusual phenomenon has been revealed; that is, during a draw operation, metal bent over the die radius must be straightened to create the cylindrical side wall of the cup. Since this metal was already work hardened by bending, a much greater force is needed for this straightening action.

c) FRICTION. At this same stage, the blank edge has been pulled in toward the punch a very noticeable amount. The draw operation gets its name from this pulling or drawing of metal toward the punch. In order for the blank edge to move in this manner, several conditions must be met. First, the force of static friction between the blank and die surface must be overcome. Usually, in draw dies, a blank holder

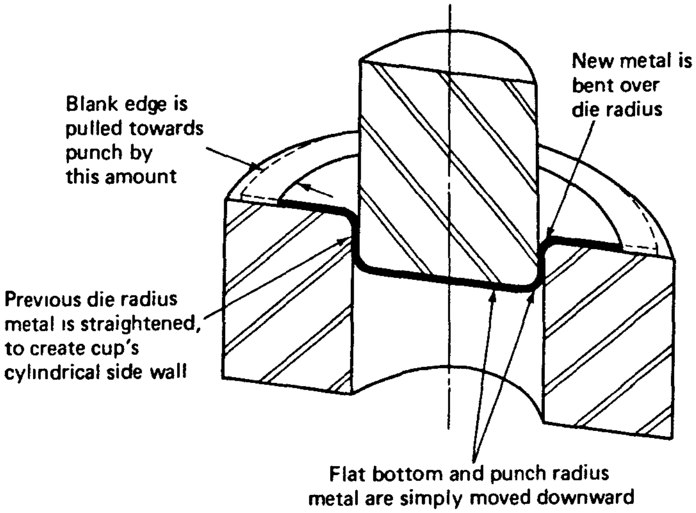
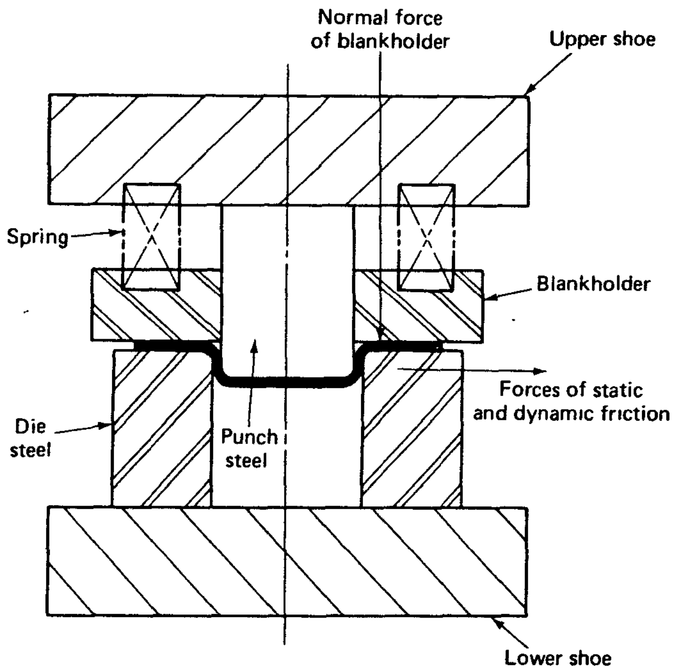


Fig. 4.4.3 Draw Action Begins With Straightening.



Coefficient of static friction (μ)
Normal force (NF)
Force due to friction (F)

$$\mu = \frac{F}{NF}$$

Fig. 4.4.4 Overcoming Forces Due to Friction.

or metal ring surrounds the punch. Friction also occurs between the blank holder and the surface of the blank. The blank holder is a pressure plate powered by springs, air cylinders, or, in large draws, the outer ram of a press. The normal force created by the blank holder adds significantly to the force of static friction. This is verified by the basic formula shown in fig. 4.4.4. After static friction has been overcome to start the blank movement, continuous force must be exerted to overcome dynamic or sliding friction. The force required to overcome dynamic friction would be less than that needed for static friction. The blank holder force must not be too large, however, or metal flow would be prevented. Lubricants or drawing compounds are usually required to reduce frictional forces.

d) COMPRESSION. Another condition required for pulling in the blank edge is that the sheet metal must be compressed. As the blank is moved inward, it must be reduced to a smaller circumference or perimeter. Likewise, all the metal between the blank edge and die radius must be squeezed to various degrees. Metal in the flat blank close to the die radius at the start of drawing would require very little squeezing. The amount of squeezing required increases for metal nearer the blank edge, as shown in fig. 4.4.5. The metal must be compressed so that it may move inward and flow over the die radius. The compression for this relatively thin sheet metal usually causes the formation of wrinkles during the drawing. The blank holder is therefore added to the draw die to prevent wrinkling when expected. Some thicker metals can be drawn without the tendency to wrinkle.

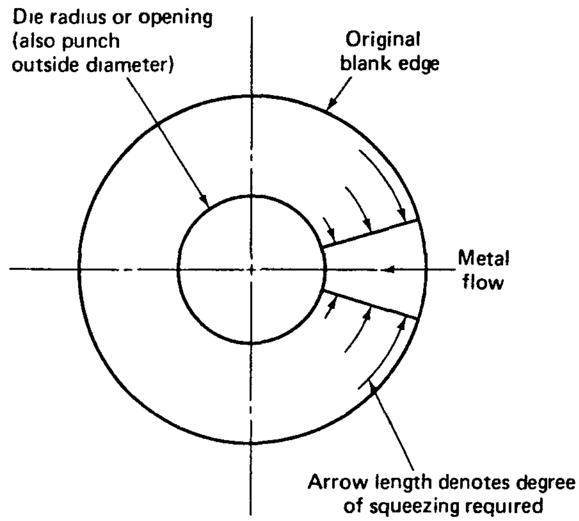


Fig. 4.4.5 Squeezing or Compression During Drawing.

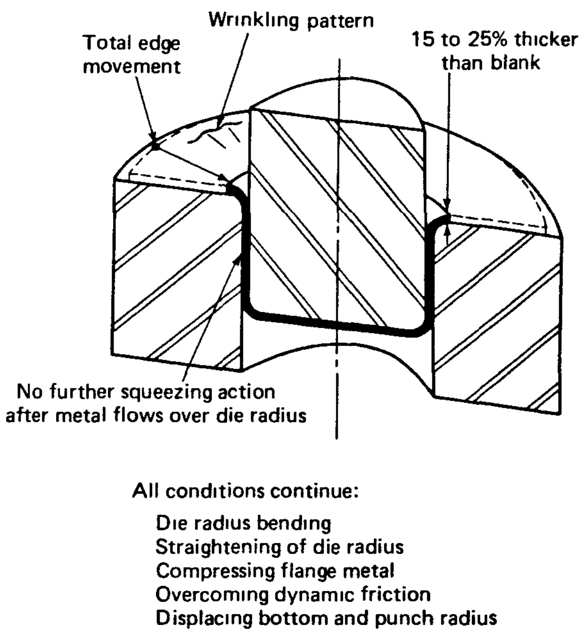


Fig. 4.4.6 Fanal Stages of Drawing.

The primary objective of drawing is to compass metal so that deep shapes can be produced without the presence of wrinkles. The final stage of drawing is shown in fig. 4.4.6.

e) TENSION. All this drawing action is created by the punch exerting a force or pushing on the flat cup bottom. The point of punch force application is somewhat remote from the points where metal shaping and friction occur. In fact, the points become more widely separated as the cup gets deeper during drawing. The cup side wall acts to transmit the punch force to the areas of bending, straitening, friction, and compression. The result is a high state of tension in the side wall as shown in fig. 4.4.7. The side wall near the punch radius is stressed the highest and becomes much thinner than the original blank. Tears will often occur at this region. Thus drawing involves a high degree of tension or stretching due to the die design used. If the blank edge could be uniformly shoved in toward a floating punch, tension would not occur during drawing. High-pressure fluids have been used to push the blank edge into the die.

f) STRETCH FORMING. Another metal-forming phase of cup drawing should not be ignored. If the cup desired should have other than a flat bottom, stretch forming will be necessary. The most common shape is the partial sphere, as shown in fig. 4.4.8. At the start of drawing, the cup's spherical bottom must be formed by stretching the sheet metal over the nose of the punch. Higher blank holder and friction forces are necessary to cause this stretch- form action. The stretch form should be nearly complete before

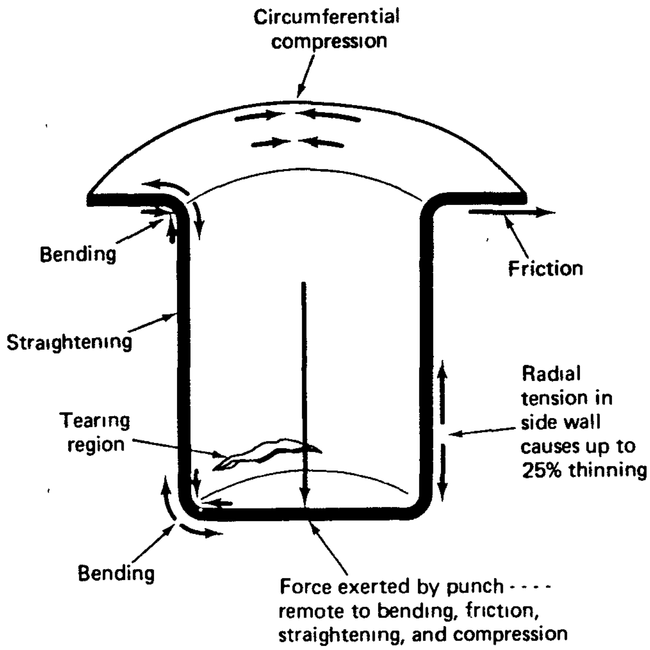


Fig. 4.4.7 Resulting Tension in Cup Side Wall.

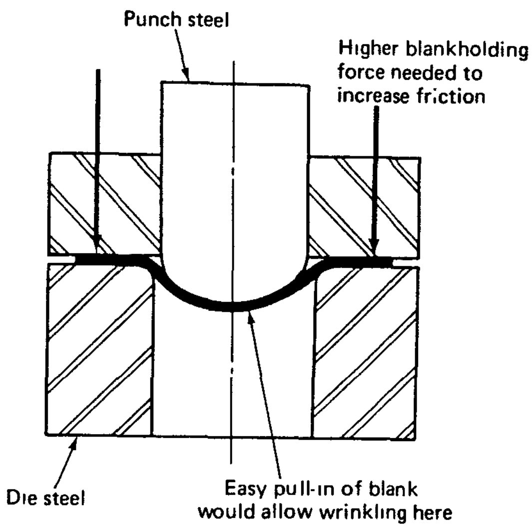


**Fig. 4.4.8 Stretch-Forming Spherical Cup Bottom
at Start of Draw.**

much blank pull-in occurs. If the blank can pull in freely, a mass of wrinkles will occur in the spherical-shaped bottom of the cup. This extra load on the sheet metal limits the depth of draw for this cup type. The region of greatest metal thinning and tears now occurs down in the spherical shape.

4.6 VARIABLES OF DRAWING

a) Bending and straightening variables. Main variables that would either increase or decrease the forces due to bending and straightening are

Punch radius, which is created by the draw punch. A sharper radius means higher bending forces.

Die radius, which is created by the die ring, is similar to punch radius. Sharper die radius means higher bending as well as straightening forces.

Degree of bend, which normally 90 degrees but may be decreased or increased by having the die surface at an angle to the horizon.

b) Friction Variables. These variables change the normal force or the coefficient of friction

Lubricant, which is applied to the sheet-metal blank or die surfaces prior to drawing. Lubricants with high slip properties reduce friction.

Blankholding force, which is the normal force causing more friction if increased.

Surface finish on both sides of sheet metal as specified by the product designer.

Surface finish of punch, die, and blank holder as created during construction.

c) **Compression Variables.** The variables that affect the required squeezing force are more difficult to comprehend.

Percent of reduction in diameter or perimeter, which is calculated using the blank diameter and the punch or cup wall diameter.

Depth of draw or height of cup also indicates a degree of compression needed.

Ductility of the sheet metal or the ability to under go a change in shape without fracturing.

Yield strength, which is the point at which permanent change of shape occurs in a metal.

Blank thickness as related to the blank diameter does effect the compression load situation.

Temperature of the blank during the draw operation.

d) **Stretch-Forming Variables.**

Olsen cupping values, which are actually the distance a steel ball has penetrated a flat sheet at the time of fracturing

Strain exponent n, which is simply the slope of the plastic region of a stress-strain curve.

e) **Miscellaneous Variables.**

Die clearance, which is the gap left between the punch and die to allow for the flow of sheet metal.

Drawing speed or the velocity at which the punch contacts the blank.

Strain ratio r or the resistance of the sheet metal to thinning. If the metal has a high ratio, there is less chance for tearing.

CHAPTER - 5

AUTOMATIC GENERATION OF PINCH OFF PUNCH AND PINCH OFF DRAWINGS USING CADL

The present project involves developing a package using CADL to automatically generate the drawings of the pinch off punch and pinch off for the following shapes.

1. Rectangular/Square
2. Round

The holepattern consists of different types and sizes of holes to assemble together the pinch off punch and pinch off. Several hole patterns are automatically created and displayed on the screen with the dimensions on it as a standard holepattern sheet. Required hole pattern number can be selected from the hole pattern standard sheet for automatically incorporating into pinch off punch or pinch off designs.

5.1 DESIGN OF PINCH OF PUNCHES AND PINCH OFFS AND THE KEY DESIGN PARAMETERS

The design of pinch off punch and pinch off for rectangular, square, and round types are done in this work. The punch, whether it is pinch off punch or pinch off, is the inside member of the assembly and is designed to accurately fit the opening in the die block. It is made of a solid block or may be built up in sections when the conditions warrant such construction. This member is made of tool steel and hardened after machining. Its size is equal to the size of the blank to be produced minus the amount allowed for die clearance. According to Vezzani[23] the die clearance varies from 5 - 10% of the thickness of the stock for harder metals; and from 10 - 18% for the softer metals. This amount is taken off each side of the punch.

The hole pattern for assembling the pinch off punch and pinch off are designed in different styles for different sizes of punches.

The punch and die design involves the following major considerations.

1. Punch radius
2. Draw ring radius
3. Punch to Die clearance, and
4. Tooling material

Each of these items affects the economy and productivity of the deep drawing process.

The software package using CADL is developed to automatically generate the drawings. Four separate programs are developed and combined into main program. Remarks are made in the program to easily identify the separate programs. The programs have been so developed that they may be used again and again for similar type of punches. The effort is directed at generalization such that just by changing the values of the input data, the drawings of the other punches can be created. The simplicity of the programs is revealed from the fact that the input data consists of only a few values of length, width, height, top radius, side radius and taper for the rectangular punches and diameter, height, bottom radius, taper and other pinch off dimensions for the round punches.

The CADL elements described in the following section are used in developing this package. The main program is presented in the Appendix.

5.2 DESCRIPTION OF CADL ELEMENTS

This section deals with the CADL elements that have been utilized for creating the drawings of rectangular and round pinch off punches and pinch offs. It has also been developed for the holepattern of the pinch off the punches.

The following9Hare the selected data primitives and their formats used for the creation of the drawings.

1. ARC - Generates a circular arc defined in a specified plane.

ARC x,y,z,rad,ang1,ang2

2. CIRCLE - This primitive describes a complete 360 degrees circular arc defined in a specified plane.

CIRCLE x,y,z,rad

3. GENDIM - A GENDIM (generic dimension) primitive describes the geometry and text used in a CADKEY generic dimension entity.

GENDIM form,nlines,narcs,arrs,arrayname,atyp,x,y,$str

4. LABEL - A LABEL primitive describes the geometry and text found in a CADKEY label dimension entity.

LABEL x1,y1,x2,y2,x3,y3,atyp,x,y,$str

5. LEADER- A LEADER primitive describes the geometry found in a CADKEY leader dimension entity.

LEADER x1,y1,x2,y2,asiz,atyp

6. LINE - The LINE primitive describes the two end points of a line in x,y,z world coordinates (model space).

LINE x1,y1,z1,x2,y2,z2

7. GETPOS- Displays a text string on the first half of the CADKEY prompt line along with the CADKEY position menu and waits until a 3D position in space is indicated using one of the options provided by the position menu.

GETPOS prompt, defopt

8. GETMENU-Displays a text string on the CADKEY prompt line and a menu in the CADKEY menu area, then waits until a menu item is selected with the function keys F1-F9 or the graphics cursor. The menu item chosen is returned in the system variable @ KEY.

GETMENU prompt, menu[,menu2,...menu9]

9. ARRAY- Allows data to be assigned to a single or multi- dimensional storage array within a CADL program. Data may be assigned before the array is used. The limit to the number of dimensions in an array is ten.

ARRAY array name[n] = {n1,n2,n3....}

10.TEXT- This primitive describes one or more strings of character assigned to a specified view plane.

TEXT x,y,$str,[ra],[ht]

11.Witness-This primitive describes the geometry found in a CADKEY witness line entity.

WITNESS x1,y1,x2,y2

12.SPRINT- This commandgives the ability to construct strings that allow to mix the numeric and string data.

SPRINT $string, "format control string", variable list

A data primitive specifies the information for an entity in the CADKEY database. When executed by the CADKEY CADL Processor; these primitives are converted to CADKEY entities and vice versa.

5.3 EDITING AND RUNNING A CADL PROGRAM

The following is the procedure of how a CADL File can be created and run. More details can be found in [24]. A method that is adequate, but slow for debugging is as follows:

1. Create a CADL program using a text editor.
2. Save the program using the DOS or UNIX naming conventions with the extension ".CDL". The file should be placed in the directory in which CADKEY will search for CADL files (specified in the CADKEY CONFIG program).
3. Enter the CADKEY program.
4. At the main Menu, choose FILES, CADL, EXECUTE.
5. The user is prompted to type in the name of the CADL program and then the program will be executed.

The preceding method is slow in DOS because CADKEY must be entered and exited every time the program is to be edited with a text editor and run again. Unix, however, allows the two programs to run at the same time. The following method allows for a much faster programming environment in DOS because the text editor can be accessed without exiting CADKEY:

1. Place the Autoswap utility (AS.EXE), found on the CADKEY utilities disk, in the directory where CADKEY resides, or in a directory where it can be accessed through a DOS path.
2. Enter CADKEY through Autoswap with the following command

AS CADKEY

3. From the Main Menu, choose CONTROL, SYSCMD, SHELL.

4. Once in the system shell, create a CADL program using a text editor.

5. Save the program using the DOS naming conventions with the extension. ".CDL". The file should be placed in the directory in which CADKEY CONFIG program.

6. After leaving the editor, type EXIT at the system prompt to return control to CADKEY.

7. From the Main Menu, choose FILES, CADL, EXECUTE.

8. It will be prompted to type in the name of the CADL program and it will be executed.

5.4 EXAMPLE RUN

As mentioned before the programs have been developed so that they may be used again and again for similar types of punches. The effort is directed at generalization such that just by changing the values of the input data, the drawings of the other punches can be created.

For creating the drawing of round pinch off punch and pinch off as shown in fig.5.1, the following data is to be entered at the prompt as given in the following. The menu can be selected either with mouse or function keys. To execute a CADL file in CADKEY, use the FILES: CADL: EXECUTE option or press F5, F4, F2. Computer will prompt

" Enter CADL file name": Enter the file name.

In this case a:program is to be entered. If an error is detected, CADL file processing halts and an error message is displayed.

Computer will ask

" Choose Option" from the displayed menu as shown below

1. R.P.O.P
2. R.P.O
3. RD.POP
4. HOLEPAT
5. EXIT

Select the option 3 i.e. round pinch off punch and pinch off . Computer will prompt for the input data as follows. The values given are the default values.

Enter Diameter = 2

Enter Height = 2

Enter Bottom Rad. = .125

Enter Taper = .001

Enter Pilot Diameter = .999

After inputting the above data computer will ask as " Define position ", press the spacebar at the lower left corner. Round pinch off punch and pinch off drawing will be automatically generated. Computer will ask " Enter P.O. dimensions " , Enter the required values as shown.

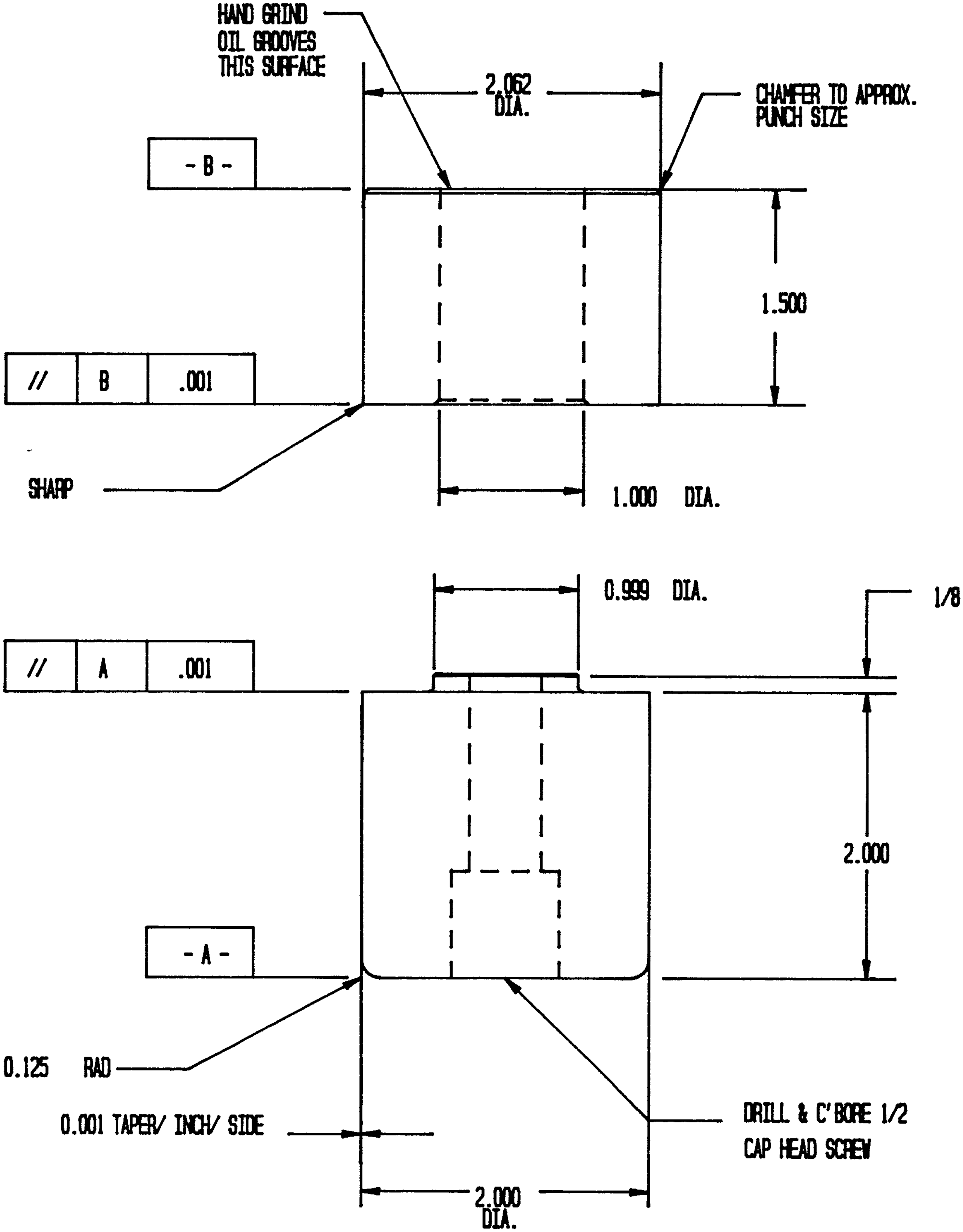
Enter pinch off Diameter = 2.062

Height = 1.5

Inner Dia. = 1

The drawing as shown in fig. 5.1 will be automatically created with all the dimensions and notes.

Similarly, the drawings of rectangular/square pinch off punch, pinch off and holepattern standard sheet are created. The drawings are as shown in figures 5.2, 5.3, and 5.4 respectively.



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REVISIONS		
NO.	DATE	DESCRIPTION

HUDSON TOOL AND DIE CO.
NEWARK, N.J.

PART NO.		FILE NO.	
DESCRIPTION ROUND P.O. PUNCH & P.O.			
CUST., DWG. NO.			
DATE 4/19/91	SCALE 1:1	WORK ORDER # FIG. 5.1	SKA-XXXX
DWN. BY BASANI V.			SHEET 1 OF 1

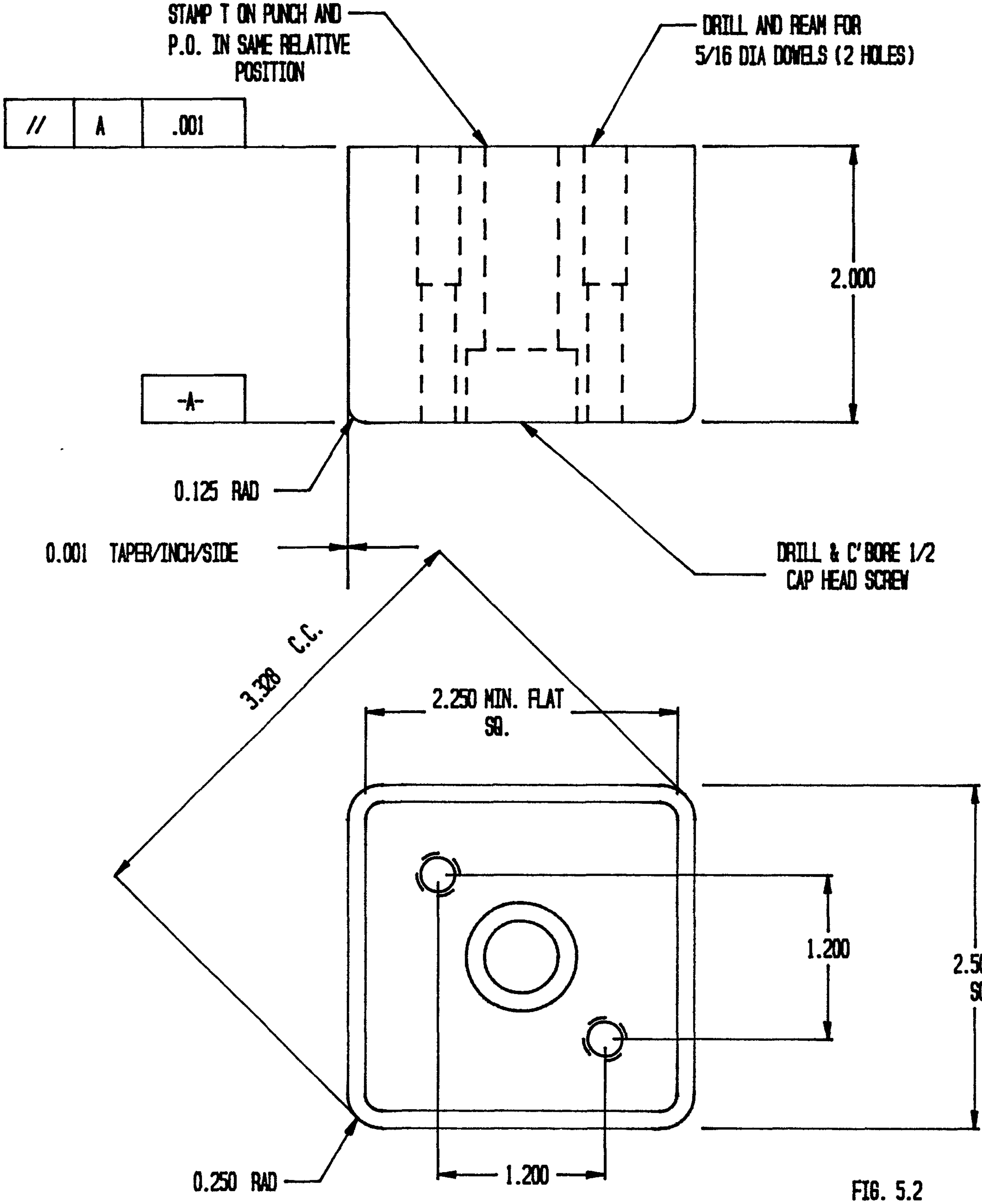
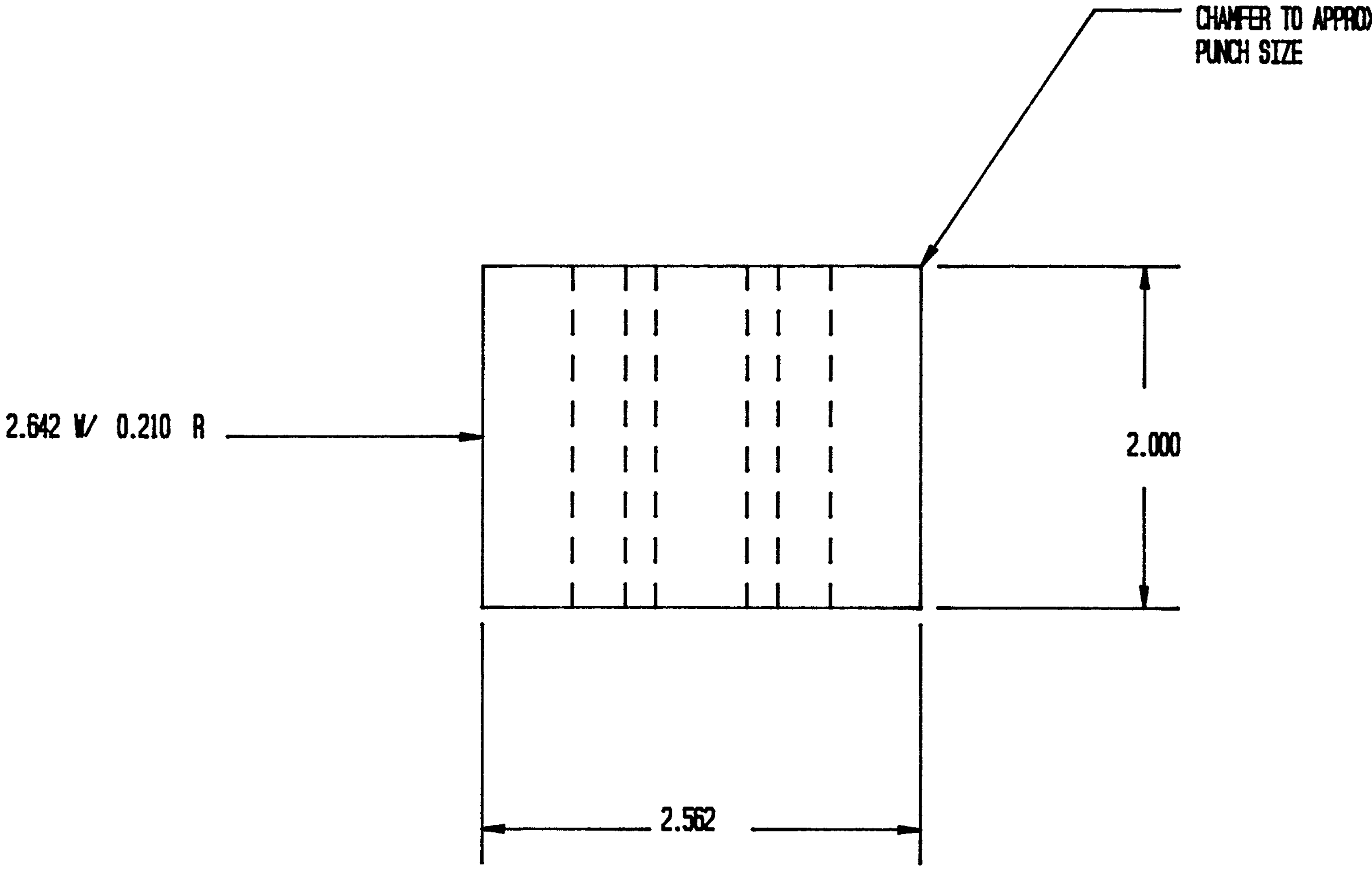


FIG. 5.2

REVISIONS		
NO.	DATE	DESCRIPTION

HUDSON TOOL AND DIE CO.
NEWARK, N.J.

PART NO.		FILE NO.	
DESCRIPTION SQUARE P.O. PUNCH			
CUST., DWG. NO.			
DATE 4/19/91	SCALE 1:1	WORK ORDER #	SKA-XXXX
DWN. BY BASANI V.			SHEET 1 OF 1



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REVISIONS		
NO.	DATE	DESCRIPTION

HUDSON TOOL AND DIE CO.

NEWARK, N.J.

PART NO.	FILE NO.
DESCRIPTION	SQUARE PINCH-OFF
CUST., DWG. NO.	
DATE 4/19/91	SCALE 1:1
DWN. BY BASANI V.	
WORK ORDER # FIG. 5.3	SKA-XXXX
SHEET 1 OF 1	

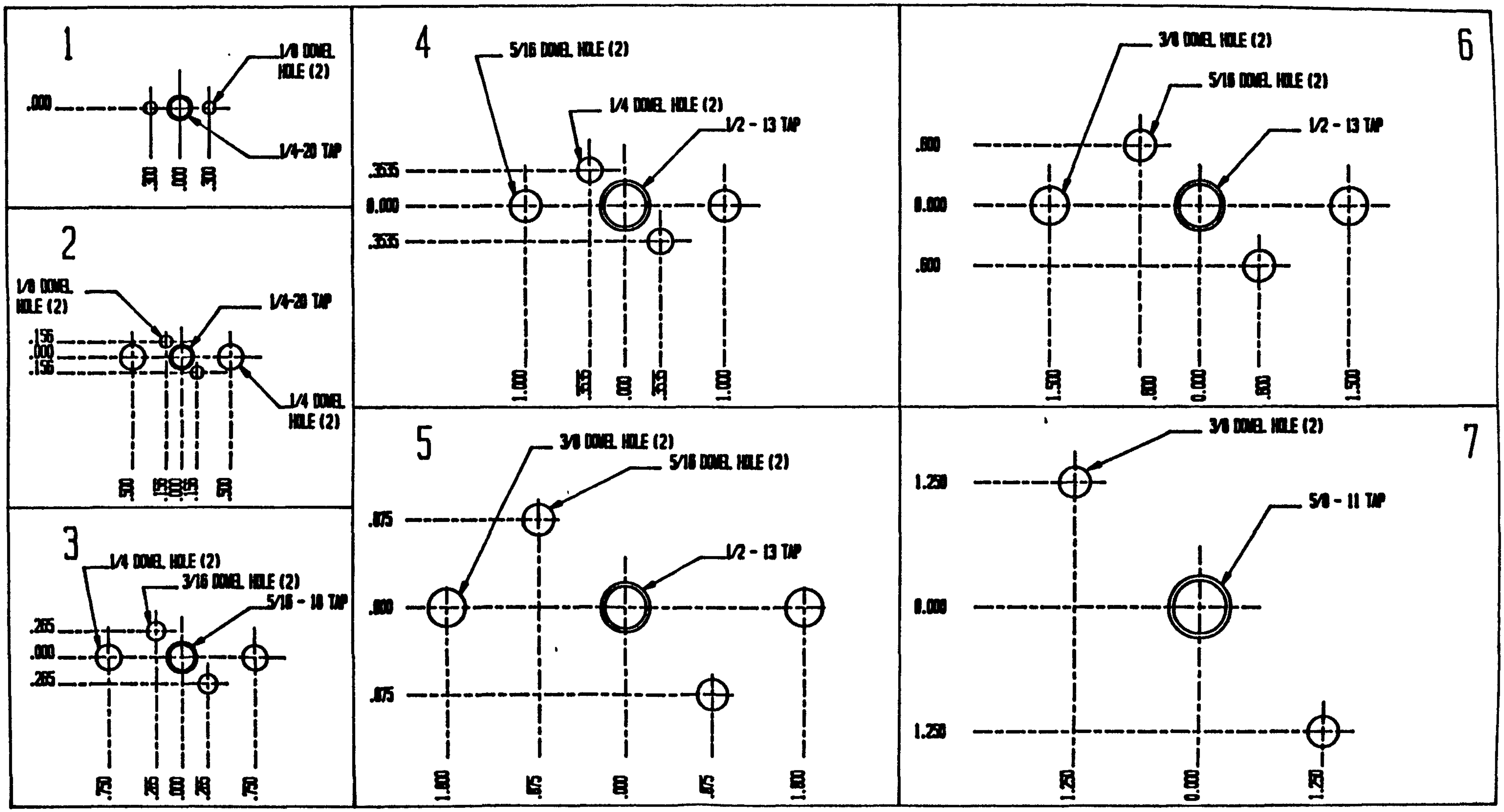

FIG. 5.4 HOLE PATTERN STANDARD SHEET

CHAPTER - 6

CONCLUSION AND SUGGESTIONS

6.1 CONCLUSION

In this project work, a software package using CADKEY and CADL for the automatic generation of drawings for already designed pinch off punch and pinch offs is developed. The same program can be used for different sizes of the pinch off punches and pinch offs and other similar designs. The program has been found to successfully generate correct drawings according to the dimensions entered by the user. It is found that through the use of the software developed here, the total design and documentation time is substantially reduced.

If necessary the drawings generated by the CADL program can be edited or changed using the CADKEY menu.

6.2 SOME SUGGESTIONS

Following suggestions are made regarding the improvement in drawings and technique for obtaining better results.

1) The present work is done by installing CADKEY software on a personal computer. As the screen dimensions are small the drawing is not clearly visible. Main frame computer is preferred for clarity.

2) Drawings can be generated quickly and efficiently in 3D perspective.

3) Program can be developed for complex punch shapes.

4) Hole patterns for any complex punch shape can be developed.

5) Punch shapes can be accepted as input data even for complex products, so that die can be designed compactly, using proper number of parts.

6) This program can be extended to progressive dies to automatically generate the drawings.

7) This can be extended to CAM by systematic processing from CAD. This saves both design and manufacturing time.

APPENDIX

CADL PROGRAM

```
rem This program is written in CADL to automatically
rem generate the drawings of rectangular, square, round
rem pinch off punches and pinch offs and hole
rem pattern standard sheet along with dimensions and notes.
rem THIS PROGRAM IS FOR RECTANGULAR/SQUARE PINCH OFF PUNCH,
rem This program creates the drawing of rectangular/square
pinch off punch
rem with all the associated dimensions on it.
:lb
getmenu "Choose
option","R.P.O.P","R.P.O","RD.POP","Holepat","Exit"
key=@key
on (key+5) goto la,lb,lb,lb,lb,lb,lc,ld,le,lf,la
:lc
getflt "Enter Lenght(%f)==>",2.5,L
getflt "Enter Width(%f)==>",2.5,W
getflt "Enter Height(%f)==>",2,H
getflt "Side Rad(%f)==>",.250,SR
getflt "Top Rad(%f)==>",.125,TR
getflt "Taper(%f)==>",.001,TP
getpos "Define Position",1
x=@xview
y=@yview
z=@zview
line x+SR,y,z,x+L-SR,y,z
line x+L,y+SR,z,x+L,y+W-SR,z
line x+L-SR,y+W,z,x+SR,y+W,z
line x,y+W-SR,z,x,y+SR,z
arc x+SR,y+SR,z,SR,180,-90,0,0,0,1,0,0,0,0
arc x+L-SR,y+SR,z,SR,270,0,0,0,0,1,0,0,0,0
arc x+L-SR,y+W-SR,z,SR,0,90,0,0,0,1,0,0,0,0
arc x+SR,y+W-SR,z,SR,90,-180,0,0,0,1,0,0,0,0
line x+SR,y+TR,z,x+L-SR,y+TR,z
line x+L-TR,y+SR,z,x+L-TR,y+W-SR,z
line x+L-SR,y+W-TR,z,x+SR,y+W-TR,z
line x+TR,y+W-SR,z,x+TR,y+SR,z
arc x+SR,y+SR,z,SR-TR,180,-90,0,0,0,1,0,0,0,0
arc x+L-SR,y+SR,z,SR-TR,270,0,0,0,0,1,0,0,0,0
arc x+L-SR,y+W-SR,z,SR-TR,0,90,0,0,0,1,0,0,0,0
arc x+SR,y+W-SR,z,SR-TR,90,-180,0,0,0,1,0,0,0,0
getflt "Enter Holepattern Number(%f)==>",1,num
array CBD[7]
CBD[0]=.422
CBD[1]=.422
CBD[2]=.515
CBD[3]=.797
CBD[4]=.797
CBD[5]=.797
CBD[6]=1
```

```
D=CBD[num-1]
circle x+L/2,y+W/2,z,D/2
array CBH[7]
CBH[0]=.28125
CBH[1]=.28125
CBH[2]=.34375
CBH[3]=.53125
CBH[4]=.53125
CBH[5]=.53125
CBH[6]=.65625
h=CBH[num-1]
array CLHD[7]
CLHD[0]=.281
CLHD[1]=.281
CLHD[2]=.3437
CLHD[3]=.5312
CLHD[4]=.5312
CLHD[5]=.5312
CLHD[6]=.6562
d=CLHD[num-1]
circle x+L/2,y+W/2,z,d/2
array CBDD[7]
CBDD[0]=.1875
CBDD[1]=.1875
CBDD[2]=.25
CBDD[3]=.3125
CBDD[4]=.3125
CBDD[5]=.3125
CBDD[6]=.4375
d2=CBDD[num-1]
array CLHDD[7]
CLHDD[0]=.125
CLHDD[1]=.125
CLHDD[2]=.1875
CLHDD[3]=.25
CLHDD[4]=.25
CLHDD[5]=.25
CLHDD[6]=.375
d1=CLHDD[num-1]
array HDH[7]
HDH[0]=.6
HDH[1]=.312
HDH[2]=.530
HDH[3]=.707
HDH[4]=1.65
HDH[5]=1.2
HDH[6]=2.5
h1=HDH[num-1]
array VDH[7]
VDH[0]=.6
VDH[1]=.312
VDH[2]=.530
VDH[3]=.707
VDH[4]=1.65
```

```
VDH[5]=1.2
VDH[6]=2.5
v1=VDH[num-1]
circle x+L/2-h1/2,y+W/2+v1/2,z,d1/2
circle x+L/2-h1/2,y+W/2+v1/2,z,d2/2,0,0,2,0,0,0,0
circle x+L/2+h1/2,y+W/2-v1/2,z,d1/2
circle x+L/2+h1/2,y+W/2-v1/2,z,d2/2,0,0,2,0,0,0,0
witness x+L/2-h1/2,y+W/2+v1/2,x+L+1.5,y+W/2+v1/2
witness x+L/2+h1/2,y+W/2-v1/2,x+L+1.5,y+W/2-v1/2
array dimhpv[14]
dimhpv[0]=x+L+1.3
dimhpv[1]=y+W/2-v1/2
dimhpv[2]=x+L+1.3
dimhpv[3]=y+W/2-.3
dimhpv[4]=x+L+1.3
dimhpv[5]=y+W/2+.3
dimhpv[6]=x+L+1.3
dimhpv[7]=y+W/2+v1/2
dimhpv[8]=x+L+1.3
dimhpv[9]=y+W/2-v1/2
dimhpv[10]=90
dimhpv[11]=x+L+1.3
dimhpv[12]=y+W/2+v1/2
dimhpv[13]=270
dist11=v1
$dim="dist11"
sprint $dim,"%.3f",dist11
gendim 50,2,0,2,dimhpv,1,x+L+1.1,y+W/2-.1,$dim,0,.125
witness x+L/2-h1/2,y+W/2+v1/2,x+L/2-h1/2,y-1.5
witness x+L/2+h1/2,y+W/2-v1/2,x+L/2+h1/2,y-1.5
array dimhph[14]
dimhph[0]=x+L/2-h1/2
dimhph[1]=y-1.3
dimhph[2]=x+L/2-.3
dimhph[3]=y-1.3
dimhph[4]=x+L/2+.3
dimhph[5]=y-1.3
dimhph[6]=x+L/2+h1/2
dimhph[7]=y-1.3
dimhph[8]=x+L/2-h1/2
dimhph[9]=y-1.3
dimhph[10]=0
dimhph[11]=x+L/2+h1/2
dimhph[12]=y-1.3
dimhph[13]=180
dist12=h1
$dim="dist12"
sprint $dim,"%.3f",dist12
gendim 50,2,0,2,dimhph,1,x+L/2-.2,y-1.3,$dim,0,.125
rem
array dimv1[14]
dimv1[0]=x+L+2.7
dimv1[1]=y
dimv1[2]=x+L+2.7
```

```
dimv1[3]=y+W/2-.3
dimv1[4]=x+L+2.7
dimv1[5]=y+W/2+.3
dimv1[6]=x+L+2.7
dimv1[7]=y+W
dimv1[8]=x+L+2.7
dimv1[9]=y
dimv1[10]=90
dimv1[11]=x+L+2.7
dimv1[12]=y+W
dimv1[13]=270
dist1=W
$dim="dist1"
sprint $dim,"%.3f",dist1
gendim 50,2,0,2,dimv1,1,x+L+2.5,y+W/2-.1,$dim,0.0,.125
rem leader x+L+2.7,y+W+2+H/2-0.2,x+L+2.7,y+W+2,0.3,2,0,0,0,\
rem 1,0,0,1
rem leaderx+L+2.7,y+W+2+H/2+0.2,x+L+2.7,y+W+2+H,0.3,2,\
rem 0,0,0,1,0,0,1
rem line x,y-.9,0,x+L/2-.3,y-.9,0
rem line x+L/2+.3,y-.9,0,x+L,y-.9,0
array dimh1[14]
dimh1[0]=x
dimh1[1]=y-2.7
dimh1[2]=x+L/2-.3
dimh1[3]=y-2.7
dimh1[4]=x+L/2+.3
dimh1[5]=y-2.7
dimh1[6]=x+L
dimh1[7]=y-2.7
dimh1[8]=x
dimh1[9]=y-2.7
dimh1[10]=0
dimh1[11]=x+L
dimh1[12]=y-2.7
dimh1[13]=180
dist=L
$dim="dist"
sprint $dim,"%.3f",dist
gendim 50,2,0,2,dimh1,1,x+L/2-.2,y-2.7,$dim,0.0,.125
witness x,y-0.1,x,y-3,0,0,0,1,0,0,1
witness x+L,y-0.1,x+L,y-3,0,0,0,1,0,0,1
witness x+L+0.1,y,x+L+3,y,0,0,0,1,0,0,1
witness x+L+0.1,y+W,x+L+3,y+W,0,0,0,1,0,0,1
witness x+L,y-.1,x+L-TP,y-.6
leader x+L-.5,y-.6,x+L-TP,y-.6,.125,1,0,0,0,1,0,0,1
leader x+L+.5,y-.6,x+L,y-.6,.125,1,0,0,0,1,0,0,1
$str=".001 -PROVIDE RELIEF 8 PLACES"
text x+L+.8,y-.65,$str,0,.125
rem
$str=" RAD"
label x-1.5,y-.75,x-1,y-.75,x+SR-.707*SR,y+SR-.707*SR,2,\
x-1.9,y-.75,$str,0,.125
siderad=SR
```

```
$dim="siderad"
sprint $dim,"%.3f",siderad
text x-2.25,y-.75,$dim,0,.125
rem
witness x+TR,y+W+.1,x+TR,y+W+.9
witness x+L-TR,y+W+.1,x+L-TR,y+W+.9
array dimh2[10]
dimh2[0]=x+TR
dimh2[1]=y+W+.6
dimh2[2]=x+L-TR
dimh2[3]=y+W+.6
dimh2[4]=x+TR
dimh2[5]=y+W+.6
dimh2[6]=0
dimh2[7]=x+L-TR
dimh2[8]=y+W+.6
dimh2[9]=180
dist2=L-2*SR
$str="dist2"
sprint $str,"%.3f",dist2
gendim 50,1,0,2,dimh2,1,x+L+.15,y+W+.55,$str,0,.125
text x+L+.6,y+W+.55,"REF FLAT TOP",0,.125
witness x-.1,y+W-TR,x-2.5,y+W-TR
witness x-.1,y+TR,x-2.5,y+TR
array dimv2[14]
dimv2[0]=x-2.2
dimv2[1]=y+TR
dimv2[2]=x-2.2
dimv2[3]=y+W/2-.3
dimv2[4]=x-2.2
dimv2[5]=y+W/2+.3
dimv2[6]=x-2.2
dimv2[7]=y+W-TR
dimv2[8]=x-2.2
dimv2[9]=y+TR
dimv2[10]=90
dimv2[11]=x-2.2
dimv2[12]=y+W-TR
dimv2[13]=270
dist3=W-2*SR
$str="dist3"
sprint $str,"%.3f",dist3
gendim 50,2,0,2,dimv2,1,x-3,y+W/2-.1,$str,0.0,.125
text x-2.4,y+W/2-.1,"REF FLAT TOP",0,.125
rem
line x+TR,y+W+3.5,z,x+L-TR,y+W+3.5,z
line x+L,y+W+3.5+TR,z,x+L,y+W+H+3.5,z
line x+L,y+W+H+3.5,z,x,y+W+H+3.5,z
line x,y+W+H+3.5,z,x,y+W+3.5+TR,z
arc x+TR,y+W+TR+3.5,z,TR,180,-90,0,0,0,,1,0,0,0,0
arc x+L-TR,y+W+TR+3.5,z,TR,270,0,0,0,0,1,0,0,0,0
line x+L/2-D/2,y+W+3.5,z,x+L/2-D/2,y+W+3.5+h,z,\
0,0,2,0,0,0,0
line x+L/2-D/2,y+W+3.5+h,z,x+L/2+D/2,y+W+3.5+h,z,\
```

```
0,0,2,0,0,0,0
line x+L/2+D/2,y+W+3.5+h,z,x+L/2+D/2,y+W+3.5,z,\
0,0,2,0,0,0,0
line x+L/2-d/2,y+W+3.5+h,z,x+L/2-d/2,y+W+H+3.5,z,\
0,0,2,0,0,0,0
line x+L/2+d/2,y+W+3.5+h,z,x+L/2+d/2,y+W+H+3.5,z,\
0,0,2,0,0,0,0
line x+L/2-h1/2-d1/2,y+W+3.5,z,\
x+L/2-h1/2-d1/2,y+W+3.5+H/2,z,0,0,2,0,0,0,0
line x+L/2-h1/2+d1/2,y+W+3.5,z,\
x+L/2-h1/2+ d1/2,y+W+3.5+H/2,z,0,0,2,0,0,0,0
line x+L/2-h1/2-d2/2,y+W+3.5+H/2,z,\
x+L/2-h1/2+d2/2,y+W+3.5+H/2,z,0,0,2,0,0,0,0
line x+L/2-h1/2-d2/2,y+W+3.5+H/2,z,\
x+L/2-h1/2-d2/2,y+W+3.5+H,z,0,0,2,0,0,0,0
line x+L/2-h1/2+d2/2,y+W+3.5+H/2,z,\
x+L/2-h1/2+d2/2,y+W+3.5+H,z,0,0,2,0,0,0,0
line x+L/2+h1/2-d1/2,y+W+3.5,z,\
x+L/2+h1/2-d1/2,y+W+3.5+H/2,z,0,0,2,0,0,0,0
line x+L/2+h1/2+d1/2,y+W+3.5,z,\
x+L/2+h1/2+d1/2,y+W+3.5+H/2,z,0,0,2,0,0,0,0
line x+L/2+h1/2-d2/2,y+W+3.5+H/2,z,\
x+L/2+h1/2+d2/2,y+W+3.5+H/2,z,0,0,2,0,0,0,0
line x+L/2+h1/2-d2/2,y+W+3.5+H/2,z,\
x+L/2+h1/2-d2/2,y+W+3.5+H,z,0,0,2,0,0,0,0
line x+L/2+h1/2+d2/2,y+W+3.5+H/2,z,\
x+L/2+h1/2+d2/2,y+W+3.5+H,z,0,0,2,0,0,0,0
witness x+L+.1,y+W+3.5,x+L+3,y+W+3.5
witness x+L+.1,y+W+H+3.5,x+L+3,y+W+H+3.5
rem line x+L+2.7,y+W+2,z,x+L+2.7,y+W+2+H/2-.3,z
rem line x+L+2.7,y+W+2+H/2+.3,z,x+L+2.7,y+W+2+H,z
array dimv3[14]
dimv3[0]=x+L+2.7
dimv3[1]=y+W+3.5
dimv3[2]=x+L+2.7
dimv3[3]=y+W+3.5+H/2-.3
dimv3[4]=x+L+2.7
dimv3[5]=y+W+3.5+H/2+.3
dimv3[6]=x+L+2.7
dimv3[7]=y+W+3.5+H
dimv3[8]=x+L+2.7
dimv3[9]=y+W+3.5
dimv3[10]=90
dimv3[11]=x+L+2.7
dimv3[12]=y+W+3.5+H
dimv3[13]=270
dist4=H
$dim="dist4"
sprint $dim,"%.3f",dist4
gendim 50,2,0,2,dimv3,1,x+L+2.5,y+W+3.5+H/2-.1,$dim,0,.125
$str="STAMP T ON PUNCH AND"
label x-1,y+W+H+5.5,x,y+W+H+5.5,x+1,y+W+H+3.5,1,x-
2.35,y+W+H+5.4,$str,0,.125
$str="P.O. IN SAME RELATIVE"
```

```
text x-2.35,y+W+H+5.2,$str,0,.125
$str="POSITION"
text x-2.35,y+W+H+5,$str,0,.125
$str="DRILL AND REAM FOR"
label
x+L/2+2,y+W+H+4.5,x+L/2+1,y+W+H+4.5,x+L/2+.5,y+W+H+3.5,1,\
x+L/2+2.1,y+W+H+4.4,$str,0,.125
$str=" 1/8 DIA DOWELS (2 HOLES) "
text x+L/2+2.1,y+W+H+4.2,$str,0,.125
witness x-0.1,y+W+H+3.5,x-2.5,y+W+H+3.5,0,0,0,1,0,0,1
witness x-2.5,y+W+H+3.5,x-2.5,y+W+H+3.5+.35,0,0,0,1,0,0,1
witness x-2.5,y+W+H+3.5+.35,x-
.75,y+W+H+3.5+.35,0,0,0,1,0,0,1
witness x-.75,y+W+H+3.5+.35,x-.75,y+W+H+3.5,0,0,0,1,0,0,1
witness x-1.5,y+W+H+3.5,x-1.5,y+W+H+3.5+.35,0,0,0,1,0,0,1
witness x-2.0,y+W+H+3.5,x-2.0,y+W+H+3.5+.35,0,0,0,1,0,0,1
$str=" // "
text x-2.4,y+W+H+3.5+0.1,$str,0.0,.125
$str=" A "
text x-1.9,y+W+H+3.5+0.1,$str,0.0,.125
$str=" .001 "
text x-1.35,y+W+H+3.5+0.1,$str,0.0,.125
witness x-0.1,y+W+3.5,x-1.5,y+W+3.5,0,0,0,1,0,0,1
witness x-1.5,y+W+3.5,x-1.5,y+W+3.5+.35,0,0,0,1,0,0,1
witness x-1.5,y+W+3.5+.35,x-.75,y+W+3.5+.35,0,0,0,1,0,0,1
witness x-.75,y+W+3.5+.35,x-.75,y+W+3.5,0,0,0,1,0,0,1
$str=" -A- "
text x-1.3,y+W+3.5+0.1,$str,0.0,.125
$str=" RAD "
label x-1.7,y+W+3,x-1.0,y+W+3,x+TR-.707*TR,y+W+3.5+TR-
.707*TR,1,\
x-2,y+W+2.9,$str,0.0,.125
toprad=TR
$dim="toprad"
sprint $dim,"%.3f",toprad
text x-2.5,y+W+2.9,$dim,0,.125
witness x,y+W+H+3.5,x,y+W+3.5-1.2,0,0,0,1,0,0,1
witness x,y+W+H+3.5,x+TP,y+W+3.5-1.2,0,0,0,1,0,0,1
leader x-0.5,y+W+3.5-0.9,x,y+W+3.5-0.9,.125,1,0,0,0,1,0,0,1
leader x+0.5,y+W+3.5-0.9,x,y+W+3.5-0.9,.125,1,0,0,0,1,0,0,1
$str=" TAPER/INCH/SIDE "
text x-1.8,y+W+3.5-1.0,$str,0.0,.125
taper=TP
$dim="taper"
sprint $dim,"%.3f",taper
text x-2.2,y+W+3.5-1,$dim,0,.125
$str="DRILL & C'BORE 1/2"
label x+L+0.5,y+W+2.4,x+L,y+W+2.4,x+L/2,y+W+3.5,1,x+L+0.6,\
y+W+2.5,$str,0.0,.125
$str=" CAP HEAD SCREW "
text x+L+0.6,y+W+2.3,$str,0.0,.125
rem
witness x+SR-.707*SR,y+SR-.707*SR,x+SR-.707*SR-.707*W,y+SR-
.707*SR+.707*W
```

```
witness x+L-SR+.707*SR,y+W-SR+.707*SR,x+L-SR+.707*SR-
.707*W,\
y+W-SR+.707*SR+.707*W
array dimd[10]
dimd[0]=x+SR-.707*SR-.707*W
dimd[1]=y+SR-.707*SR+.707*W
dimd[2]=x+L-SR+.707*SR-.707*W
dimd[3]=y+W-SR+.707*SR+.707*W
dimd[4]=x+SR-.707*SR-.707*W
dimd[5]=y+SR-.707*SR+.707*W
dimd[6]=45
dimd[7]=x+L-SR+.707*SR-.707*W
dimd[8]=y+W-SR+.707*SR+.707*W
dimd[9]=225
diag=sqrt((L-2*SR+2*.707*SR)^2+(W-2*SR+2*.707*SR)^2)
$dim="diag"
sprint $dim,"%.3f",diag
gendim 50,1,0,2,dimd,1,x-.7,y+W+.55,$dim,45,.125
$str="C.C."
text x-.35,y+W+.95,$str,45,.125
goto lb
:ld
rem THIS PROGRAM IS FOR RECTANGULAR/SQUARE PINCH OFF PUNCH.
rem This program creates the drawing of rectangular/square
pinch off
rem with the associted dimensions and notes on it.
getflt "Enter Pinch off B dimn.(%f)==>",2.562,D
getflt "Enter Height(%f)==>",2,H
getflt "Enter Pinch off A dimn.(%f)==>",2.642,A
getflt "Enter Pinch off Rad.(%f)==>",.210,PR
getpos "Define Position",1
x=@xview
y=@yview
z=@zview
getflt "Enter Holepattern Number(%d)==>",1,num
array CLHD[7]
CLHD[0]=.281
CLHD[1]=.281
CLHD[2]=.3437
CLHD[3]=.5312
CLHD[4]=.5312
CLHD[5]=.5312
CLHD[6]=.6562
d=CLHD[num-1]
array CLHDD[7]
CLHDD[0]=.125
CLHDD[1]=.125
CLHDD[2]=.1875
CLHDD[3]=.25
CLHDD[4]=.3125
CLHDD[5]=.3125
CLHDD[6]=.375
d1=CLHDD[num-1]
array HDH[7]
```

```
HDH[0]=.6
HDH[1]=.312
HDH[2]=.530
HDH[3]=.707
HDH[4]=1.65
HDH[5]=1.2
HDH[6]=2.5
DD=HDH[num-1]
line x,y,z,x+D,y,z
line x+D,y,z,x+D,y+H,z
line x+D,y+H,z,x,y+H,z
line x,y+H,z,x,y,z
line x+D/2-d/2,y,z,x+D/2-d/2,y+H,z,0,0,2,0,0,0,0
line x+D/2+d/2,y,z,x+D/2+d/2,y+H,z,0,0,2,0,0,0,0
line x+D/2-DD/2-d1/2,y,z,x+D/2-DD/2-d1/2,y+H,z,0,0,2,0,0,0,0
line x+D/2-DD/2+d1/2,y,z,x+D/2-DD/2+d1/2,y+H,z,0,0,2,0,0,0,0
line x+D/2+DD/2-d1/2,y,z,x+D/2+DD/2-d1/2,y+H,z,0,0,2,0,0,0,0
line x+D/2+DD/2+d1/2,y,z,x+D/2+DD/2+d1/2,y+H,z,0,0,2,0,0,0,0
rem
witness x,y-0.1,x,y-1.5,0,0,0,1,0,0,1
witness x+D,y-0.1,x+D,y-1.5,0,0,0,1,0,0,1
array dimh1[14]
dimh1[0]=x
dimh1[1]=y-1.3
dimh1[2]=x+D/2-.3
dimh1[3]=y-1.3
dimh1[4]=x+D/2+.3
dimh1[5]=y-1.3
dimh1[6]=x+D
dimh1[7]=y-1.3
dimh1[8]=x
dimh1[9]=y-1.3
dimh1[10]=0
dimh1[11]=x+D
dimh1[12]=y-1.3
dimh1[13]=180
dist=D
$dim="dist"
sprint $dim,"%.3f",dist
gendim 50,2,0,2,dimh1,1,x+D/2-.23,y-1.3,$dim,0.0,.125
witness x+D+.1,y,x+D+1.5,y
witness x+D+.1,y+H,x+D+1.5,y+H
array dimv1[14]
dimv1[0]=x+D+1.3
dimv1[1]=y
dimv1[2]=x+D+1.3
dimv1[3]=y+H/2-.3
dimv1[4]=x+D+1.3
dimv1[5]=y+H/2+.3
dimv1[6]=x+D+1.3
dimv1[7]=y+H
dimv1[8]=x+D+1.3
dimv1[9]=y
dimv1[10]=90
```

```
dimv1[11]=x+D+1.3
dimv1[12]=y+H
dimv1[13]=270
dist1=H
$dim="dist1"
sprint $dim,"%.3f",dist1
gendim 50,2,0,2,dimv1,1,x+D+1.2,y+H/2-.1,$dim,0,.125
rem
$str="CHAMFER TO APPROX"
label x+D+1.5,y+H+1.5,x+D+1,y+H+1.5,x+D,y+H,1,\
x+D+1.6,y+H+1.4,$str,0,.125
$str="PUNCH SIZE"
text x+D+1.6,y+H+1.2,$str,0,.125
leader x-1.5,y+H/2,x,y+H/2,0.125,1,0,0,0,1,0,0,1
pinchoffA=A
$dim="pinchoffA"
sprint $dim,"%.3f",pinchoffA
text x-2.8,y+H/2,$dim,0,.125
$dim="W/"
text x-2.4,y+H/2,$dim,0,.125
pinchoffRad=PR
$dim="pinchoffRad"
sprint $dim,"%.3f",pinchoffRad
text x-2.15,y+H/2,$dim,0,.125
$dim="R"
text x-1.7,y+H/2,$dim,0,.125
goto lb
:le
rem THIS PROGRAM IS FOR ROUND PINCH OFF PUNCH AND PINCH OFF.
rem This program creates the drawing of round pinch off
punch and
rem pinch off with associated dimensions on it.
getflt "Enter Diameter(%f)==>",2,D
getflt "HEIGHT(%f)==>",3,H
getflt "BOTTOM RAD(%f)==>",.125,BR
getflt "TAPER(%f)==>",0.001,TP
getflt "Enter Pilot Dia.(%f)==>",.999,PD
getpos "Define Position",1
x=@xview
y=@yview
z=@zview
line x+TP+BR,y,z,x+D-BR-TP,y,z
arc x+D-BR-TP,y+BR,z,BR,270,0,0,0,0,1,0,0,0,0
line x+D-TP,y+BR,z,x+D,y+H,z
line x+D,y+H,z,x,y+H,z
line x,y+H,z,x+TP,y+BR,z
arc x+TP+BR,y+BR,z,BR,180,-90,0,0,0,1,0,0,0,0
arc x+D/2-PD/2-.0312,y+H+.0312,z,.0312,270,0,0,0,0,1,0,0,0,0
line x+D/2-PD/2,y+H+.0312,z,x+D/2-PD/2,y+H+.11,z
line x+D/2-PD/2,y+H+.11,z,x+D/2+PD/2,y+H+.11,z
line x+D/2+PD/2,y+H+.11,z,x+D/2+PD/2,y+H+.0312,z
arc x+D/2+PD/2+.0312,y+H+.0312,z,.0312,180,-90,0,0,0,1,\
0,0,0,0
line x+D/2-PD/2,y+H+.11,z,x+D/2-PD/2+.015,y+H+.11+.015,z
```

```
line x+D/2-PD/2+.015,y+H+.11+.015,z,x+D/2+PD/2-.015,\
y+H+.11+.015,z
line x+D/2+PD/2-.015,y+H+.11+.015,z,x+D/2+PD/2,y+H+.11,z
line x+D/2-.75/2,y,z,x+D/2-.75/2,y+.75,z,0,0,2,0,0,0,0
line x+D/2-.75/2,y+.75,z,x+D/2+.75/2,y+.75,z,0,0,2,\
0,0,0,0
line x+D/2+.75/2,y+.75,z,x+D/2+.75/2,y,z,0,0,2,0,0,0,0
line x+D/2-.5/2,y+.75,z,x+D/2-.5/2,y+H+.125,z,0,0,2,0,0,0,0
line x+D/2+.5/2,y+.75,z,x+D/2+.5/2,y+H+.125,z,0,0,2,0,0,0,0
witness x-.1,y,x-1.5,y,0,0,0,1,0,0,1
witness x-1.5,y,x-1.5,y+.35,0,0,0,1,0,0,1
witness x-1.5,y+.35,x-.75,y+.35,0,0,0,1,0,0,1
witness x-.75,y+.35,x-.75,y,0,0,0,1,0,0,1
$str=" - A - "
text x-1.3,y+.1,$str,0.0,.125
$str=" RAD "
label x-1.7,y-.65,x-1.2,y-.65,x,y,1,x-2,y-.7,$str,0,.125
bottomrad=BR
$dim="bottomrad"
sprint $dim,"%.3f",bottomrad
text x-2.5,y-.7,$dim,0,.125
witness x,y+H-.1,x,y-1.3,0,0,0,1,0,0,1
witness x,y,x+.001,y-1.3,0,0,0,1,0,0,1
leader x-.5,y-1.1,x,y-1.1,.125,1,0,0,0,1,0,0,1
leader x+.001+.5,y-1.1,x+.001,y-1.1,.125,1,0,0,0,1,0,0,1
$str=" TAPER/ INCH/ SIDE "
text x-1.8,y-1.1,$str,0.0,.125
taper=TP
$dim="taper"
sprint $dim,"%.3f",taper
text x-2.1,y-1.1,$dim,0,.125
$str=" DRILL & C'BORE 1/2 "
label x+D+.5,y-1,x+D,y-1,x+D/2,y,1,x+D+.6,y-1,$str,0,.125
$str=" CAP HEAD SCREW "
text x+D+.6,y-1.25,$str,0.0,.125
witness x-.1,y+H,x-2.5,y+H,0,0,0,1,0,0,1
witness x-2.5,y+H,x-2.5,y+H+.35,0,0,0,1,0,0,1
witness x-2.5,y+H+.35,x-.75,y+H+.35,0,0,0,1,0,0,1
witness x-.75,y+H+.35,x-.75,y+H,0,0,0,1,0,0,1
witness x-1.5,y+H,x-1.5,y+H+.35,0,0,0,1,0,0,1
witness x-2.0,y+H,x-2.0,y+H+.35,0,0,0,1,0,0,1
$str=" // "
text x-2.4,y+H+.1,$str,0.0,.125
$str=" A "
text x-1.9,y+H+.1,$str,0.0,.125
$str=" .001 "
text x-1.35,y+H+.1,$str,0.0,.125
rem
rem getflt "ENTER P.O. DIMENSIONS",1
getflt "Enter Pinch Off DIAMETER(%f)==>",2.062,POD
getflt "HEIGHT(%f)==>",1.5,POH
getflt "INNER DIA.(%f)==>",1,PID
line x,y+H+2,z,x+POD,y+H+2,z
line x+POD,y+H+2,z,x+POD,y+H+2+POH-.031,z
```

```
line x+POD,y+H+2+POH-.031,z,x,y+H+2+POH-.031,z
line x,y+H+2+POH-.031,z,x,y+H+2,z
line x,y+H+2+POH-.031,z,x+.031,y+H+2+POH,z
line x+.031,y+H+2+POH,z,x+POD-.031,y+H+2+POH,z
line x+POD-.031,y+H+2+POH,z,x+POD,y+H+2+POH-.031,z
line x+POD/2-PID/2-0.0312,y+H+2,z,x+POD/2-PID/2,\
y+H+2+.0312,z,0,0,2,0,0,0,0
line x+POD/2-PID/2,y+H+2+.0312,z,x+POD/2+PID/2,y+H+2+.0312,\
z,0,0,2,0,0,0,0
line x+POD/2+PID/2,y+H+2+.0312,z,x+POD/2+PID/2+.0312,y+H+2,\
z,0,0,2,0,0,0,0
line x+POD/2-PID/2,y+H+2+.0312,z,x+POD/2-PID/2,y+H+2+POH,z,\
0,0,2,0,0,0,0
line x+POD/2+PID/2,y+H+2+.0312,z,x+POD/2+PID/2,y+H+2+POH,z,\
0,0,2,0,0,0,0
$str=" HAND GRIND "
label x-1,y+H+POH+4,x-.2,y+H+POH+4,x+.6,y+H+POH+2,1,x-2,\
y+H+POH+4,$str,0.0,.125
$str=" OIL GROOVES "
text x-2,y+H+POH+3.8,$str,0.0,.125
$str=" THIS SURFACE "
text x-2,y+H+POH+3.6,$str,0.0,.125
$str=" CHAMFER TO APPROX. "
label x+POD+2,y+H+POH+3,x+POD+1,y+H+POH+3,x+POD,y+H+2+POH,\
1,x+POD+2.1,y+H+POH+3,$str,0.0,.125
$str=" PUNCH SIZE "
text x+POD+2.1,y+H+POH+2.8,$str,0.0,.125
$str=" SHARP "
label x-1.8,y+H+1.4,x-1,y+H+1.4,x,y+H+2,1,x-2.4,y+H+1.35,\
$str,0.0,.125
witness x-.1,y+H+2+POH,x-1.5,y+H+2+POH,0,0,0,1,0,0,1
witness x-1.5,y+H+2+POH,x-1.5,y+H+POH+2.35,0,0,0,1,0,0,1
witness x-1.5,y+H+POH+2.35,x-.75,y+H+POH+2.35,0,0,0,1,0,0,1
witness x-.75,y+H+POH+2.35,x-.75,y+H+POH+2,0,0,0,1,0,0,1
$str=" - B - "
text x-1.3,y+H+POH+2.1,$str,0,.125
witness x-.1,y+H+2,x-2.5,y+H+2,0,0,0,1,0,0,1
witness x-2.5,y+H+2,x-2.5,y+H+2.35,0,0,0,1,0,0,1
witness x-2.5,y+H+2.35,x-.75,y+H+2.35,0,0,0,1,0,0,1
witness x-.75,y+H+2.35,x-.75,y+H+2,0,0,0,1,0,0,1
witness x-1.5,y+H+2,x-1.5,y+H+2.35,0,0,0,1,0,0,1
witness x-2,y+H+2,x-2,y+H+2.35,0,0,0,1,0,0,1
$str=" // "
text x-2.4,y+H+2.1,$str,0,.125
$str=" B "
text x-1.9,y+H+2.1,$str,0,.125
$str=" .001 "
text x-1.35,y+H+2.1,$str,0,.125
witness x,y+H+2+POH-.031-.1,x,y+H+2+POH-.031-.1+1
witness x+POD,y+H+2+POH-.031-.1,x+POD,y+H+2+POH-.031-.1+1
array dimh1[14]
dimh1[0]=x+POD/2-.25
dimh1[1]=y+H+2+POH-.031-.1+.8
dimh1[2]=x
```

```
dimh1[3]=y+H+2+POH-.031-.1+.8
dimh1[4]=x+POD/2+.25
dimh1[5]=y+H+2+POH-.031-.1+.8
dimh1[6]=x+POD
dimh1[7]=y+H+2+POH-.031-.1+.8
dimh1[8]=x
dimh1[9]=y+H+2+POH-.031-.1+.8
dimh1[10]=0
dimh1[11]=x+POD
dimh1[12]=y+H+2+POH-.031-.1+.8
dimh1[13]=180
dia1=POD
$dim="dia1"
sprint $dim,"%.3f",dia1
gendim 50,2,0,2,dimh1,1,x+POD/2-.18,y+H+2+POH-.031\
-.1+.8,$dim,0,.125
$str=" DIA. "
text x+POD/2-.16,y+H+2+POH-.031-.1+.5,$str,0,.125
witness x+POD-.1,y+H+2,x+POD+1,y+H+2
witness x+POD-.1,y+H+2+POH,x+POD+1,y+H+2+POH
array dimv1[14]
dimv1[0]=x+POD+.8
dimv1[1]=y+H+2
dimv1[2]=x+POD+.8
dimv1[3]=y+H+2+.5
dimv1[4]=x+POD+.8
dimv1[5]=y+H+2+POH
dimv1[6]=x+POD+.8
dimv1[7]=y+H+2+POH-.5
dimv1[8]=x+POD+.8
dimv1[9]=y+H+2
dimv1[10]=90
dimv1[11]=x+POD+.8
dimv1[12]=y+H+2+POH
dimv1[13]=270
height1=POH
$dim="height1"
sprint $dim,"%.3f",height1
gendim 50,2,0,2,dimv1,1,x+POD+.7,y+H+1.9+POH/2,$dim,0,.125
witness x+POD/2-PID/2,y+H+2-.05,x+POD/2-PID/2,y+H+1.35-.05
witness x+POD/2+PID/2,y+H+2-.05,x+POD/2+PID/2,y+H+1.35-.05
array dimh2[10]
dimh2[0]=x+POD/2-PID/2
dimh2[1]=y+H+1.4
dimh2[2]=x+POD/2+PID/2
dimh2[3]=y+H+1.4
dimh2[4]=x+POD/2-PID/2
dimh2[5]=y+H+1.4
dimh2[6]=0
dimh2[7]=x+POD/2+PID/2
dimh2[8]=y+H+1.4
dimh2[9]=180
dia2=PID
$dim="dia2"
```

```
sprint $dim,"%.3f",dia2
gendim 50,1,0,2,dimh2,1,x+POD/2+PID/2+.2,y+H+1.3,$dim,0,.125
$str=" DIA. "
text x+POD/2+PID/2+.65,y+H+1.3,$str,0,.125
rem
witness x+D/2-PD/2,y+H+.11+.05,x+D/2-PD/2,y+H+.11+.7
witness x+D/2+PD/2,y+H+.11+.05,x+D/2+PD/2,y+H+.11+.7
array dimh3[10]
dimh3[0]=x+D/2-PD/2
dimh3[1]=y+H+.11+.6
dimh3[2]=x+D/2+PD/2
dimh3[3]=y+H+.11+.6
dimh3[4]=x+D/2-PD/2
dimh3[5]=y+H+.11+.6
dimh3[6]=0
dimh3[7]=x+D/2+PD/2
dimh3[8]=y+H+.11+.6
dimh3[9]=180
dia3=PD
$dim="dia3"
sprint $dim,"%.3f",dia3
gendim 50,1,0,2,dimh3,1,x+D/2+PD/2+.18,y+H+.1+.55,\
$dim,0,.125
$Str="DIA."
text x+D/2+PD/2+.6,y+H+.1+.55,$str,0,.125
witness x,y+H-.1,x,y-1.6
witness x+D,y+H-.1,x+D,y-1.6
array dimh4[14]
dimh4[0]=x
dimh4[1]=y-1.5
dimh4[2]=x+D/2-.25
dimh4[3]=y-1.5
dimh4[4]=x+D/2+.25
dimh4[5]=y-1.5
dimh4[6]=x+D
dimh4[7]=y-1.5
dimh4[8]=x
dimh4[9]=y-1.5
dimh4[10]=0
dimh4[11]=x+D
dimh4[12]=y-1.5
dimh4[13]=180
dia4=D
$dim="dia4"
sprint $dim,"%.3f",dia4
gendim 50,2,0,2,dimh4,1,x+D/2-.20,y-1.6,$dim,0,.125
$str="DIA."
text x+D/2-.15,y-1.75,$str,0,.125
witness x+D+.1,y,x+D+1.7,y
witness x+D+.1,y+H,x+D+1.7,y+H
array dimv2[14]
dimv2[0]=x+D+1.5
dimv2[1]=y
dimv2[2]=x+D+1.5
```

```
dimv2[3]=y+H/2-.3
dimv2[4]=x+D+1.5
dimv2[5]=y+H/2+.3
dimv2[6]=x+D+1.5
dimv2[7]=y+H
dimv2[8]=x+D+1.5
dimv2[9]=y
dimv2[10]=90
dimv2[11]=x+D+1.5
dimv2[12]=y+H
dimv2[13]=270
height2=H
$dim="height2"
sprint $dim,"%.3f",height2
gendim 50,2,0,2,dimv2,1,x+D+1.45,y+H/2-.1,$dim,0,.125
witness x+D/2+PD/2-.015+.1,y+H+.11,x+D+1.7,y+H+.11
$str=" 1/8"
label x+D+1.5+.3,y+H+.11+.6,x+D+1.5,y+H+.11+.6,x+D+1.5,\
y+H+.11,1,x+D+1.5+.4,y+H+.11+.5,$str,0,.125
goto lb
:lf
rem THIS PROGRAM IS FOR STANDARD HOLE PATTERN SHEET.
rem This program creates the standard hole patterns for
pinch off punch
rem and pinch off with the dimensions on it.
getpos "Define position",1
x=@xview
y=@yview
z=@zview
line x,y,z,x+15,y,z
line x+15,y,z,x+15,y+8,z
line x+15,y+8,z,x,y+8,z
line x,y+8,z,x,y,z
line x+3.5,y,z,x+3.5,y+8,z
line x,y+3.0,z,x+3.5,y+3,z
line x,y+6,z,x+3.5,y+6,z
line x+9,y,z,x+9,y+8,z
line x+3.5,y+4,z,x+15,y+4,z
rem 1
text x+.4,y+7.5," 1 ",0,.3
circle x+1.75,y+7,z,0.1005
circle x+1.75,y+7,z,0.125
circle x+1.75-.3,y+7,z,0.0625
circle x+1.75+.3,y+7,z,0.0625
$str="1/8 DOWEL"
label x+2.75,y+7.5,x+2.45,y+7.5,x+1.75+.3+.044,y+7+.044,2,\
x+2.76,y+7.5,$str,0,.125
text x+2.76,y+7.3,"HOLE (2)",0,.125
$str="1/4-20 TAP"
label x+2.75,y+6.5,x+2.45,y+6.5,x+1.75+.088,y+7-.088,2,\
x+2.76,y+6.5,$str,0,.125
line x+1.75-1.25,y+7,z,x+1.75+.5,y+7,z,0,0,3
text x+1.75-1.55,y+7,".000",0,.125
line x+1.75-.3,y+7.2,z,x+1.75-.3,y+6.5,z
```

```
text x+1.75-.25,y+6.15,".300",90,.125
line x+1.75,y+7.37,z,x+1.75,y+6.5,z
text x+1.8,y+6.15,".000",90,.125
line x+1.75+.3,y+7.2,z,x+1.75+.3,y+6.5,z
text x+1.75+.35,y+6.15,".300",90,.125
rem 2
text x+.4,y+5.5," 2 ",0,.3
circle x+1.75,y+4.5,z,.1005
circle x+1.75,y+4.5,z,.125
circle x+1.75-.156,y+4.5+.156,z,.0625
circle x+1.75+.156,y+4.5-.156,z,.0625
circle x+1.75-.5,y+4.5,z,.125
circle x+1.75+.5,y+4.5,z,.125
$str="1/4-20 TAP"
label x+1.75+.8,y+4.5+.5,x+1.75+.4,y+4.5+.5,x+1.75+.088,\
y+4.5+.088,2,x+1.75+.9,y+4.5+.5,$str,0,.125
$str="1/8 DOWEL"
label x+1.75-.156-.8,y+4.5+.156+.5,x+1.75-.156-.5,\
y+4.5+.156+.5,x+1.75-.156-.044,y+4.5+.156+.044,2,\
x+1.75-.156-.8-.7,y+4.5+.156+.5,$str,0,.125
text x+1.75-.156-.8-.7,y+4.3+.156+.5,"HOLE (2)",0,.125
$str="1/4 DOWEL"
label x+2.05+.8,y+4.5-.5,x+2.25+.5,y+4.5-.5,x+1.75+.5\
+.088,y+4.5-.088,2,x+2.05+.8,y+4.5-.5,$str,0,.125
text x+2.05+.8,y+4.5-.7,"HOLE (2)",0,.125
line x+1.75-1.25,y+4.5,z,x+1.75+.5+.3,y+4.5,z,0,0,3
text x+1.75-1.55,y+4.5,".000",0,.125
line x+1.75-1.25,y+4.5+.156,z,x+1.75-
.156+.3,y+4.5+.156,z,0,0,3
text x+1.75-1.55,y+4.5+.156,".156",0,.125
line x+1.75-1.25,y+4.5-.156,z,x+1.75+.156+.3,y+4.5-
.156,z,0,0,3
text x+1.75-1.55,y+4.5-.156,".156",0,.125
line x+1.75-.5,y+4.5+.25,z,x+1.75-.5,y+3.4,z,0,0,3
text x+1.75-.5,y+3.05,".500",90,.125
line x+1.75-.156,y+4.5+.156+.1,z,x+1.75-.156,y+3.4,z,0,0,3
text x+1.75-.156,y+3.05,".156",90,.125
line x+1.75,y+4.5+.3,z,x+1.75,y+3.4,z,0,0,3
text x+1.75,y+3.05,".000",90,.125
line x+1.75+.156,y+4.5-.156+.1,z,x+1.75+.156,y+3.4,z,0,0,3
text x+1.75+.156,y+3.05,".156",90,.125
line x+1.75+.5,y+4.5+.25,z,x+1.75+.5,y+3.4,z,0,0,3
text x+1.75+.5,y+3.05,".500",90,.125
rem  3
text x+.4,y+2.5," 3 ",0,.3
circle x+1.75,y+1.5,z,.128
circle x+1.75,y+1.5,z,.156
circle x+1.75-.265,y+1.5+.265,z,.094
circle x+1.75+.265,y+1.5-.265,z,.094
circle x+1.75-.75,y+1.5,z,.125
circle x+1.75+.75,y+1.5,z,.125
$str="5/16 - 18 TAP"
label
x+2.65,y+1.5+.5,x+2.45,y+1.5+.5,x+1.75+.11,y+1.5+.11,2,\
```

```
x+2.63,y+1.5+.5,$str,0,.125
$str="3/16 DOWEL HOLE (2)"
label x+1.7,y+1.5+.7,x+1.75-.4,y+1.5+.7,x+1.75-.265-
.066,y+1.5+.265+.066,\
2,x+1.76,y+1.5+.7,$str,0,.125
$str="1/4 DOWEL HOLE (2)"
label x+1.75-.75,y+1.5+.9,x+1.75-1.0,y+1.5+.9,x+1.75-.75-
.088,y+1.5+.088,2,\
x+1.76-.75,y+1.5+.9,$str,0,.125
line x+1.75-1.25,y+1.5+.265,z,x+1.75-
.265+.2,y+1.5+.265,z,0,0,3
text x+1.75-1.55,y+1.5+.265,".265",0,.125
line x+1.75-1.25,y+1.5,z,x+1.75+.75+.3,y+1.5,z,0,0,3
text x+1.75-1.55,y+1.5,".000",0,.125
line x+1.75-1.25,y+1.5-.265,z,x+1.75+.265+.2,y+1.5-
.265,z,0,0,3
text x+1.75-1.55,y+1.5-.265,".265",0,.125
line x+1.75-.75,y+1.5+.3,z,x+1.75-.75,y+.4,z,0,0,3
text x+1.75-.75,y+.05,".750",90,.125
line x+1.75-.265,y+1.5+.265+.2,z,x+1.75-.265,y+.4,z,0,0,3
text x+1.75-.265,y+.05,".265",90,.125
line x+1.75,y+1.5+.4,z,x+1.75,y+.4,z,0,0,3
text x+1.75,y+.05,".000",90,.125
line x+1.75+.265,y+1.5-.265+.2,z,x+1.75+.265,y+.4,z,0,0,3
text x+1.75+.265,y+.05,".265",90,.125
line x+1.75+.75,y+1.5+.3,z,x+1.75+.75,y+.4,z,0,0,3
text x+1.75+.75,y+.05,".750",90,.125
rem 4
text x+4,y+7.5," 4 ",0,.3
circle x+6.25,y+6,z,.211
circle x+6.25,y+6,z,.25
circle x+6.25-.3535,y+6+.3535,z,.125
circle x+6.25+.3535,y+6-.3535,z,.125
circle x+6.25-1,y+6,z,.156
circle x+6.25+1,y+6,z,.156
$str="1/2 - 13 TAP"
label x+7.25,y+6.75,x+7,y+6.75,x+6.25+.177,y+6+.177,2,\
x+7.26,y+6.75,$str,0,.125
$str="1/4 DOWEL HOLE (2)"
label x+6,y+6.95,x+5.7,y+6.95,x+6.25-.3535-
.088,y+6+.3535+.088,2,\
x+6.1,y+6.95,$str,0,.125
$str="5/16 DOWEL HOLE (2)"
label x+5,y+7.5,x+4.75,y+7.5,x+5.25-.11,y+6+.11,2,\
x+5.1,y+7.5,$str,0,.125
line x+6.25-1.8-.4,y+6+.3535,z,x+6.25-
.3535+.3,y+6+.3535,z,0,0,3
text x+6.25-1.8-.8,y+6+.3035,".3535",0,.125
line x+6.25-1.8-.4,y+6,z,x+6.25+1+.35,y+6,z,0,0,3
text x+6.25-1.8-.8,y+5.95,"0.000",0,.125
line x+6.25-1.8-.4,y+6-.3535,z,x+6.25+.3535+.3,y+6-
.3535,z,0,0,3
text x+6.25-1.8-.8,y+6-.4035,".3535",0,.125
line x+6.25-1,y+4.4,z,x+6.25-1,y+6+.4,z,0,0,3
```

```
text x+6.25-1,y+4.05,"1.000",90,.125
line x+6.25-.3535,y+4.4,z,x+6.25-.3535,y+6+.3535+.3,z,0,0,3
text x+6.25-.3535,y+4.05,".3535",90,.125
line x+6.25,y+4.4,z,x+6.25,y+6+.6,z,0,0,3
text x+6.3,y+4.05,".000",90,.125
line x+6.25+.3535,y+4.4,z,x+6.25+.3535,y+6-.3535+.3,z,0,0,3
text x+6.3+.3535,y+4.05,".3535",90,.125
line x+6.25+1,y+4.4,z,x+6.25+1,y+6+.4,z,0,0,3
text x+6.25+1.05,y+4.05,"1.000",90,.125
rem  5
text x+4,y+3.5," 5 ",0,.3
circle x+6.25,y+2,z,.211
circle x+6.25,y+2,z,.25
circle x+6.25-.875,y+2+.875,z,.156
circle x+6.25+.875,y+2-.875,z,.156
circle x+6.25-1.8,y+2,z,.1875
circle x+6.25+1.8,y+2,z,.1875
$str="1/2 - 13 TAP"
label x+7.25,y+2.5,x+7,y+2.5,x+6.25+.177,y+2+.177,2,\
x+7.26,y+2.5,$str,0,.125
$str="5/16 DOWEL HOLE (2)"
label x+6.6,y+3.4,x+6.3,y+3.4,x+6.25-
.875+.11,y+2+.875+.11,2,\
x+6.7,y+3.4,$str,0,.125
$str="3/8 DOWEL HOLE (2)"
label x+5.5,y+3.6,x+5.3,y+3.6,x+6.25-1.8+.132,y+2+.132,2,\
x+5.6,y+3.6,$str,0,.125
line x+6.25-1.8-.4,y+2,z,x+6.25+1.8+.2,y+2,z,0,0,3
text x+6.25-1.8-.8,y+1.95,".000",0,.125
line x+6.25-1.8-.4,y+2+.875,z,x+6.25-
.875+.2,y+2+.875,z,0,0,3
text x+6.25-1.8-.8,y+2+.825,".875",0,.125
line x+6.25-1.8-.4,y+2-.875,z,x+6.25+.875+.2,y+2-
.875,z,0,0,3
text x+6.25-1.8-.8,y+2-.925,".875",0,.125
line x+6.25-1.8,y+2+.2,z,x+6.25-1.8,y+.5,z,0,0,3
text x+6.25-1.8,y+.05,"1.800",90,.125
line x+6.25-.875,y+2+.875+.2,z,x+6.25-.875,y+.5,z,0,0,3
text x+6.25-.875,y+.05,".875",90,.125
line x+6.25,y+2+.5,z,x+6.25,y+.5,z,0,0,3
text x+6.25,y+.05,".000",90,.125
line x+6.25+.875,y+2-.875+.2,z,x+6.25+.875,y+.5,z,0,0,3
text x+6.25+.875,y+.05,".875",90,.125
line x+6.25+1.8,y+2+.2,z,x+6.25+1.8,y+.5,z,0,0,3
text x+6.25+1.8,y+.05,"1.800",90,.125
rem  6
text x+14.5,y+7.5," 6 ",0,.3
circle x+12,y+6,z,.211
circle x+12,y+6,z,.25
circle x+12-.6,y+6+.6,z,.156
circle x+12+.6,y+6-.6,z,.156
circle x+12-1.5,y+6,z,.187
circle x+12+1.5,y+6,z,.187
$str="1/2 - 13 TAP"
```

```
label x+13,y+6.75,x+12.7,y+6.75,x+12+.177,y+6+.177,2,\
x+13.1,y+6.75,$str,0,.125
$str="5/16 DOWEL HOLE (2)"
label x+12,y+7.2,x+11.7,y+7.2,x+12-.6+.11,y+6+.6+.11,2,\
x+12.1,y+7.2,$str,0,.125
$str="3/8 DOWEL HOLE (2)"
label x+11.5,y+7.6,x+11.2,y+7.6,x+12-1.5+.132,y+6+.132,2,\
x+11.6,y+7.6,$str,0,.125
line x+12-2.25,y+6+.6,z,x+12-.6+.3,y+6+.6,z,0,0,3
text x+12-2.25-.6,y+6+.55,".600",0,.125
line x+12-2.25,y+6,z,x+12+1.5+.4,y+6,z,0,0,3
text x+12-2.25-.6,y+5.95,"0.000",0,.125
line x+12-2.25,y+6-.6,z,x+12+.6+.3,y+6-.6,z,0,0,3
text x+12-2.25-.6,y+6-.65,".600",0,.125
line x+12-1.5,y+4.4,z,x+12-1.5,y+6+.4,z,0,0,3
text x+12-1.4,y+4.05,"1.500",90,.125
line x+12-.6,y+4.4,z,x+12-.6,y+6+.6+.3,z,0,0,3
text x+12-.45,y+4.05,".600",90,.125
line x+12,y+4.4,z,x+12,y+6+.4,z,0,0,3
text x+12.05,y+4.05,"0.000",90,.125
line x+12+.6,y+4.4,z,x+12+.6,y+6-.6+.3,z,0,0,3
text x+12+.7,y+4.05,".600",90,.125
line x+12+1.5,y+4.4,z,x+12+1.5,y+6+.4,z,0,0,3
text x+12+1.6,y+4.05,"1.500",90,.125
rem this belongs to 6
rem  7
text x+14.5,y+3.5," 7 ",0,.3
circle x+12,y+2,z,.2656
circle x+12,y+2,z,.3125
circle x+12-1.25,y+2+1.25,z,.156
circle x+12+1.25,y+2-1.25,z,.156
$str="5/8 - 11 TAP"
label x+13,y+3,x+12.7,y+3,x+12+.22,y+2+.22,2,\
x+13.1,y+3,$str,0,.125
$str="3/8 DOWEL HOLE (2)"
label x+12,y+3.75,x+11.7,y+3.75,x+12-
1.25+.132,y+2+1.25+.132,2,\
x+12.1,y+3.75,$str,0,.125
line x+12-2.25,y+3.25,z,x+12-1.25+.3,y+3.25,z,0,0,3
text x+12-2.25-.6,y+3.2,"1.250",0,.125
line x+12-2.25,y+2,z,x+12+.6,y+2,z,0,0,3
text x+12-2.25-.6,y+1.95,"0.000",0,.125
line x+12-2.25,y+2-1.25,z,x+12+1.25+.3,y+2-1.25,z,0,0,3
text x+12-2.25-.6,y+2-1.30,"1.250",0,.125
line x+12-1.25,y+.4,z,x+12-1.25,y+2+1.25+.3,z,0,0,3
text x+12-1.25,y+.05,"1.250",90,.125
line x+12,y+.4,z,x+12,y+2+.6,z,0,0,3
text x+12,y+.05,"0.000",90,.125
line x+12+1.25,y+.4,z,x+12+1.25,y+2-1.25+.3,z,0,0,3
text x+12+1.25,y+.05,"1.250",90,.125
goto lb
:la
exit
```

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