CAD/CAM OF DIES

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PREFACE

Die design and manufacturing for metal forming has an industrial history spanning more than a few centuries. During the last 25 years, as a result of spectacular technological advances, the economical importance of metal-forming processes, associated die design and manufacturing processes has increased considerably. The computer has become the key element in the integration of design, analysis, and manufacturing functions.

CAD/CAM has found a wide range of applications in all areas of engineering, design, and manufacturing. While the developments and applications of CAD/CAM technology in certain areas have been wide-spread, its application in other areas, such as die design and manufacturing, has been fairly limited.

This book is an expanded version of two monographs which the author and some of his colleagues have been requested to write for the ASM and SME Handbooks. It contains the latest technology in CAD/CAM of dies based on the experience of the authors and on the most important recent publications in this area.

The book is intended to provide a comprehensive introduction to the complex subject of the CAD/CAM of dies for those in industry, R & D organizations and universities, with particular reference to advances in materials technology, analytical modelling, and computers and graphics technology. It will provide valuable, detailed information to both undergraduate and graduate students as well as researchers in this field and may well be used as a text for special courses in CAD/CAM, materials technology, and die design and manufacturing technology.

This book could not have been completed without the collaboration of many acknowledged experts, in particular the process modelling group of Dr. H. L. Gegel of the U.S. Air Force Materials Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio. Special thanks are due to Dr. Sokka Doraivelu, Technical Director, Universal Energy Systems, and Messers James Malas, James Morgan, and Richard Kavaulaskas, Air Force Wright Aeronautical Laboratories, WPAFB, for their assistance and cooperation in the areas of analytical and physical modelling. Thanks are also due to my past and present students both from Australia and the U.S.A., associates in my company – Super Technology International, in particular Research Associates Amer Ali and Anis Ahmed, and Bhavin Mehta, Manager Intergraph CAD System at Ohio University, who have made valuable contributions to the material in this book.

A book of this nature could not have been completed without the research and development efforts of various scientists and engineers throughout the world. In that connection, I wish to mention the following additional names and organizations who in my opinion have contributed most to the advancement of the CAD/CAM dies: Dr. Taylan Altan, Battelle Columbus Laboratories (presently at Ohio State University); Prof. K. K. Wang, Cornell University; Dr. W. Knight, Oxford University, U.K., (presently with University of Rhode Island); Dr. John Berry, Georgia Institute of Technology; Drs. R. Davis and H. Siauw, Manufacturing Technology Division, CSIRO, Australia, and their respective research groups.

Finally, it would have been impossible for me to complete this book without the constant encouragement and help of my former supervisor, Professor John M. Alexander at Imperial College, U.K., and the understanding of my wife, Mal and daughters, Manisha and Upendri. I dedicate this book to my parents, Mal, Manisha, Upendri, and Professor Alexander.

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15th Sep. 1988

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Chapter 1

INTRODUCTION AND GENERAL PRINCIPLES

1.1 Computers and CAD/CAM

Computers first appeared in the 1940's. The early inventions were bulky, cumbersome to use and performed computations rather slowly in comparison to modern digital computers. They advanced from mechanical relays to vacuum tubes to transistors to silicon chips. Computers today are more compact, faster and less expensive than their predecessors. Today some microcomputers can handle the computations of early day main-frames. Technological advances in this field have been truly dramatic.

The application areas of computers have also grown rapidly. Computers are widely used in the fields of Engineering, Business, Education and Medicine. However, the most spectacular growth has been in the area of CAD/CAM – Computer Aided Design and Computer Aided Manufacture. This new technology, which emerged within the last decade or so, has helped to increase Engineering productivity tremendously. Higher productivity is probably the primary consideration that influences most potential users to acquire a CAD/CAM system. CAD/CAM provides the integration of design, analysis and manufacturing functions into a system which is available to the user at his fingertips. In addition, other routine and monotonous (but important) tasks such as the preparation of bills of materials, costing, production scheduling, etc. may be performed automatically using the same computer network. Another major benefit in the use of CAD/CAM is reduced lead time from concept to design to manufacture. Product development cost can also be reduced dramatically because analysis such as the finite element method can be interfaced with design to arrive at the optimum design within a very short time.

CAD/CAM and Analysis are best used in an interactive, computer graphics environment to provide solutions to engineering problems as illustrated in Fig. 1.1. The geometry and topology of the part and other parameters such as material properties are stored in a common data base which can be accessed by any one of the functions. Analysis such as finite element methods, upper bound methods and slab analysis is carried out on the initial product geometry.

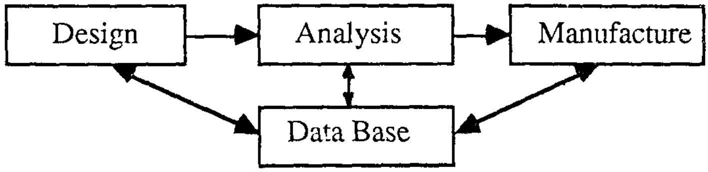

Fig. 1.1 Interactive computer graphics environment

Results which are often displayed in colour will either automatically or with user interventions alter the design parameters so as to satisfy the various design criteria. This process is repeated until an optimum solution is obtained. Thereafter manufacturing and other related functions can be performed either automatically or with user intervention.

1.2 CAD/CAM System

Any CAD/CAM system consists of hardware, such as the central processing unit (CPU), disk storage facilities, display units, tablets, etc. and software, which is the brain behind the system. Sometimes it is harder to make a clear distinction between the two, when hardware is built-in with appropriate software. This is often referred to as "firmware."

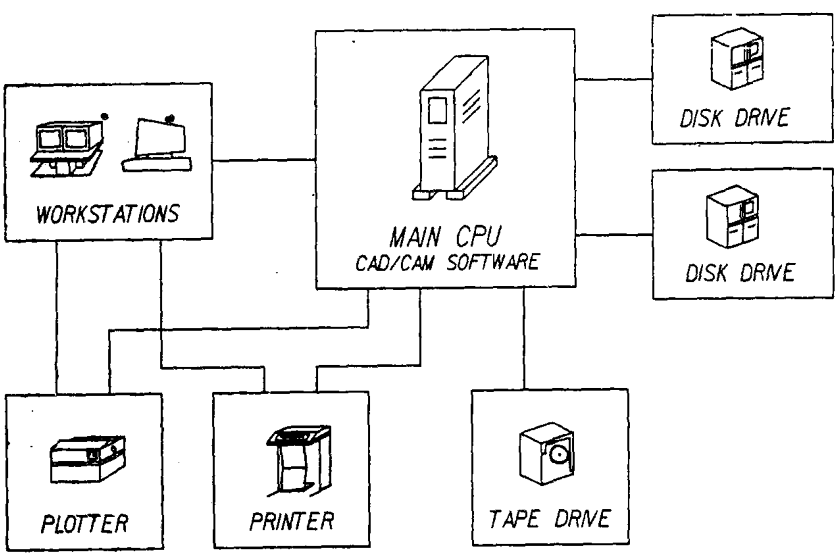

Fig. 1.2 Typical CAD/CAM system configuration

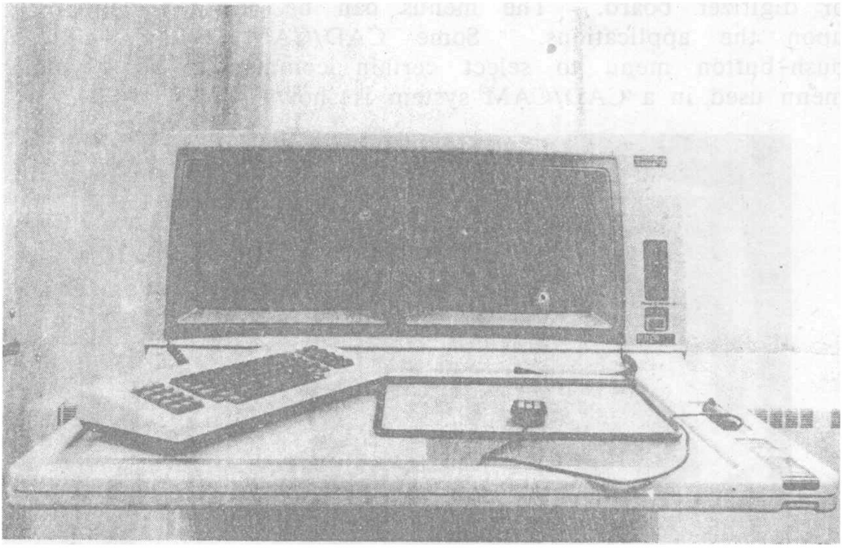

Fig. 1.3 Typical CAD/CAM work station
(Courtesy of Intergraph Corp.)

A typical CAD/CAM system configuration is illustrated in Fig. 1.2. The heart of the system is the central processing unit (or the computer), which coordinates all the functions within the CAD/CAM system. The user interacts with the system through the work station. A typical work station is shown in Fig. 1.3. It consists of a graphic display (or two, as in this case) which provides visual output of the system to the user. The user can communicate with the system through the keyboard or a tablet (with menu) as shown in Fig. 1.4. The dual-screen work-station has numerous advantages. It can be used to view the product being designed at two or more angles. The zoom command may be used to zoom up a certain feature of the product on one screen for detail view while the other screen can be used to view the whole part. Text may be entered on any one of the screens. Other vendors have systems with graphic display and an alpha-numeric display for text.

The work stations (Fig. 1.5) are intelligent, in that they do useful local operations such as zoom, rotate, etc, without tying up the CPU for these operations. The current trend is to increase the power of the work station, thus freeing the CPU for other more demanding tasks. Many CAD/CAM systems have a "menu" of commands to choose from a tablet or digitizer board. The menus can be changed depending upon the applications. Some CAD/CAM systems use a push-button menu to select certain commands. A typical menu used in a CAD/CAM system is shown in Fig. 1.6.

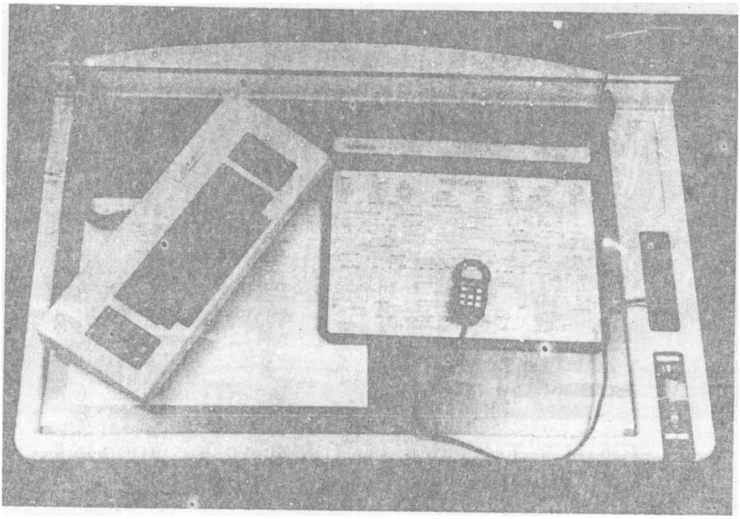

Fig. 1.4 Typical CAD/CAM tablet with menu

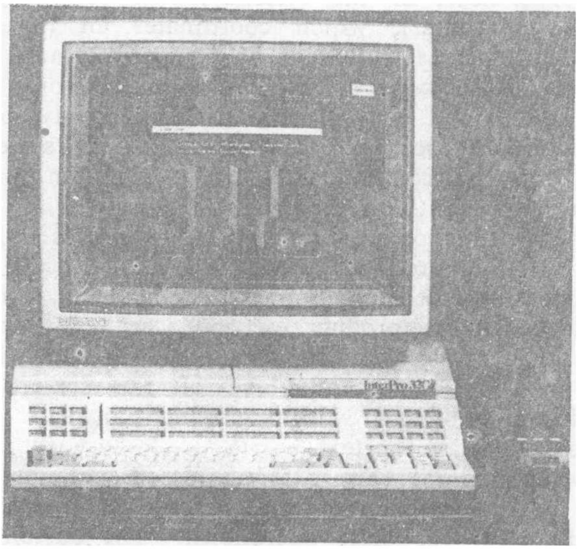

Fig. 1.5 Typical graphic and alpha-numeric displays (Courtesy of Intergraph Corp.)

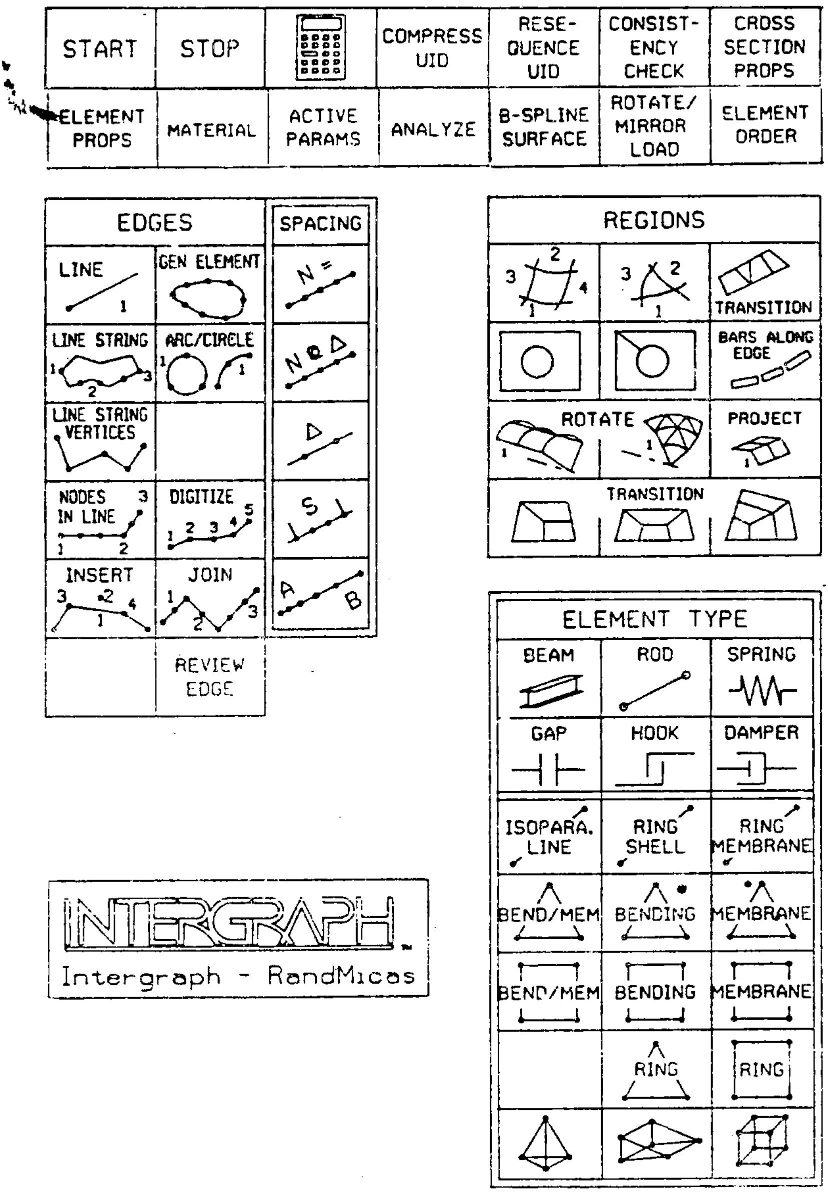

Fig. 1.6 Typical CAD/CAM menu
(Courtesy of Intergraph Corp.)

1.3 Die Making

Die making has been an art more than a science. The design and manufacture of dies have been passed down for decades from die and tool designers and tool makers to their apprentices and so on. This process is undergoing some revolutionary changes with the advent of computers, CAD/CAM technology and powerful analysis such as the finite element method. Details of these will be presented in the following chapters of this book.

Dies for processes such as hot forging, extrusion, casting, and plastics moulding are usually produced by manual machining, copy milling or by electric discharge machining (EDM). In the conventional EDM process the electrode is frequently manufactured by copy milling from a suitable pattern. EDM is particularly useful for die manufacture as it can be employed for intricate shapes in hard-to-machine materials. Most of the common methods used in die making involve highly skilled time-consuming manual operations. The use of CAD/CAM for die making has substantial benefits, as will be demonstrated in the following chapters.

The dies considered in this book for CAD/CAM and analysis fall into the following categories:-

a) Hot forging dies for metals
b) Hot extrusion dies for metals
c) Cold extrusion dies for metals
d) Die casting dies for non-ferrous metals
e) Sand casting dies for ferrous metals
f) Polymer extrusion dies
g) Plastics moulding dies

However, because of the author's personal experience with hot extrusion dies for metals, detailed discussion (design, analysis and manufacturing) will be limited to these dies. Because of the similarity of the analysis and manufacturing (and some design) functions, the techniques presented here are equally applicable to most of the types of dies mentioned above.

MANUFACTURING PROCESSES AND CONVENTIONAL DIE DESIGN

2.1 Introduction

Dies and moulds are used in a variety of manufacturing processes. By far the largest use has been in the manufacture of discrete parts using metals and plastics. Manufacturing using dies and moulds offers numerous advantages over other manufacturing methods such as machining and joining processes. When medium to large production runs are involved, moulding and forming methods become superior in terms of lower unit costs and better mechanical properties. Material utilization is very high with most processes utilizing dies and moulds. If proper processing conditions are maintained, rejection rates become very low. Production rates are usually very high and overall high productivity of the manufacturing operation can be achieved.

There are inherent advantages of the extrusion and forging processes of making discrete parts. Fundamentally, these processes shape metals under high pressure. This controlled deformation of material (usually performed at elevated temperature) results in metallurgical soundness and improved mechanical properties. The following advantages are specifically for the extrusion and forging processes, but some may well equally apply to other manufacturing processes considered here:

*Superior mechanical properties
*Ability to process modern heretofore "unprocessable" materials such as P/M alloys and fibre reinforced composites.
*Extreme reliability
*Closer tolerance capabilities
*High strength
*Structural integrity
*High impact and fatigue resistance
*High uniformity
*Wide range of sizes
*Wide range of materials

*Low rejection rates
*Economy of machining
*High material utilization

This chapter provides detailed descriptions of the extrusion process and of the concepts of conventional die design. Other manufacturing processes and associated die designs are also briefly mentioned.

2.2 Extrusion Process and Die Design

Extrusion is a metal forming process in which a billet is forced to flow through a die to form a product of uniform cross-section along its length. The billet is usually of circular cross-section, whereas the desired product may have any shape for its cross-section. There are two common types of extrusion dies, viz.:-

(i) the so-called "flat-faced" or "shear" die which is commonly used in the extrusion of aluminium; and

(ii) the "shaped" or "converging" die which has found applications in the lubricated extrusion of titanium, nickel and steel alloys (Fig. 2.1).

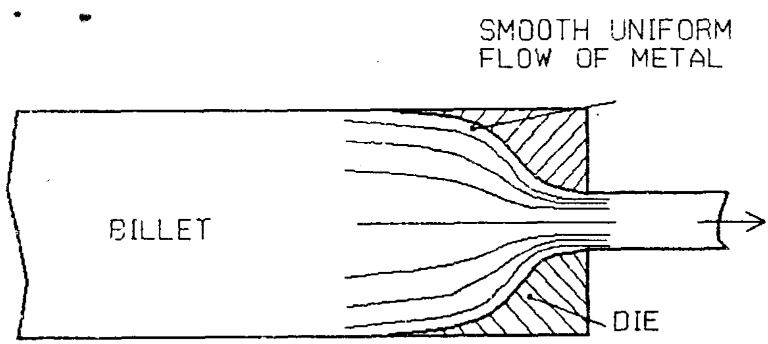

Fig. 2.1 Shaped extrusion die