LOW COST GEOMETRIC MODELLING SYSTEM FOR CAM

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ABSTRACT

A geometric modelling system is implemented on a low cost, medium resolution, colour graphics workstation. When compared with other CAD/CAM systems for the design and manufacture of engineering components, the proposed system is more oriented towards the manufacturing of 3-dimensional geometric model using Numerical Control machine. The colour graphics capability allows a designer to interactively create simple 3-dimensional geometric shapes as the building blocks for complex 3-dimensional engineering component. By "shape operation" on the building blocks interactively with feed back from the graphical screen, the final design as appeared on the graphical screen can then be manufactured by Numerical Control machine subject to designer specified manufaturing parameters such as Numerical Control machine cutter size and the degree of surface finishing.

KEYWORDS: building blocks, CAD, CAM, cutter path, geometric modelling, Numerical Control machining, shape operation

INTRODUCTION

Currently, there are various CAD/CAM systems available commercially. The application areas covered by these systems range from Computer Aided drafting in building architecture(1) to design and manufacture of sculpture surfaces(2). Another application area is the CAD/CAM of engineering components for the production and mechanical engineering industry. Some better known research and commercially available systems addressing the needs of the engineering industry are PADL(3) and ROMULUS(4). Although these two systems are usually referred to as CAD/CAM systems, the geometric models produced by these systems in research publications and advertising brochures in fact tend to demonstrate visual realism rather than physical realism in the form of physical models manufactured by Numerical Control machine. The system proposed in here is a CAD/CAM system with emphasis on CAM and yet offer design capability to a designer. In as far as using the proposed system is concerned, there can be two approaches. One approach is the traditional practice in which a specification drawing is already available and the user simply interprets the drawing and discretise the complex engineering drawing specification into many "building blocks". The building blocks are then "shape operated" to reproduce the engineering component visually on the graphical screen as well as physically by Numerical Control machine. To put it simply, the user can be considered as a "part programmer" responsible for producing a physical model based on a specification drawing. When compared with part programming language such as APT(5) to produce a physical model, the power and the ease-of-use of the proposed system can be easily seen. Furthermore, the turnaround time will only be a matter of hours even for a complex engineering component compared with a matter of days or weeks when using APT or its equivalent. The other way in which the system can be used is that the designer would directly input his design idea into the system in the form of "building blocks". By placing the "building blocks" appropriately and "shape operating" them interactively on the graphical screen, a design can then be obtained. A design as displayed on the graphical screen can then be made available in digital format for engineering analysis. The final approved design can then be produced physically by Numerical Control machine.

The hardware configuration on which the system is implemented is a Seiko-9500 which consists of three processors/co-processor. These are Intel 8086, 8087 running at 5 MHz and a 8088 running at 8 MHz. The 8086 and 8087 are used for executing load module obtained by linking various object modules compiled from a number of Pascal source programs. The 8 MHz 8088 is dedicated to I/O and is used as a "graphics processor" for an eight colour raster display of 512 by 480 resolution. The system has 512 K-bytes of memory and two 5.25-inch floppy disk drives giving 1.2 M-bytes of storage. The operating system is a customised version of Intel iRMX86. In developing the software, an external winchester is used.

AN OVERVIEW OF THE PROPOSED SYSTEM

The proposed system allows a designer/part-programmer to interact with it in order to produce a design and subsequently produce a physical model of the design by the use of a Numerical Control milling machine.

In as far as a typical user of the proposed system is concerned a session on the system is typically divided into three distinct phases. The first phase can be best described as the initialisation phase which basically prepares the ground work for performing the second and the third phase. The second phase of a session allows the user to interactively create "building blocks" from PRIMITIVES available in the system. The third and final phase is the "placement and shape operation" of previously created building blocks incrementally on the graphical screen of the Seiko-9500 until a final design is obtained for Numerical Control machine milling to produce a physical 3-dimensional engineering component.

THE INITIALISATION PHASE

The proposed system is oriented towards CAM of engineering components by Numerical Control milling. The two most important ingradients which enable the proposed system to be a genuine CAM system are the "creation of building blocks from primitives in the system" and the subsequent "placement and shape operation of the building blocks". However, it is necessary to make preparations before the creation of building blocks and shape operation can take place.

When a user enters the proposed system, he must first define

(1) an area defined by length and width in millimeters on the x-y plane onto which a Numerical Control machine would perform the NC milling,

(2) the cutter size to be used on the Numerical Control machine in millimeters,

(3) the degree of surface finishing specified in millimeters,

(4) the number of building blocks to be created from each of the primitives available in the system.

THE PHASE OF CREATING BUILDING BLOCKS

One of the features of the system is that "building blocks" can be created which are subsequently "shape operated" upon to form a complex engineering component. When using the system, building blocks can be created by assigning physical dimensions to "PRIMITIVES" available from the system. Currently, there are six primitives in the system from which building blocks can be created. These are

(i) CONE
(ii) ARC-BLOCK
(iii) ELLIPSOID
(iv) PRISM
(v) TOROID
(vi) HORIZONTAL CONE

Although there are only six primitives available in the system for creating building blocks, the variety of building blocks that can be generated from these six primitives are tremendous. Figure 1 gives a tree structure representation of the primitives and the variations that can be obtained from these six primitives.

When using the system to create a building block from any one of the above primitives, the user is require to input various parameters. These parameters include:

(a) the Numerical Control machine cutter size for NC milling the building block currently being created,

(b) the degree of surface finishing for the building block currently being created,

(c) the physical characteristics of the building block which are usually length, width, vertical height, etc..

A typical building block created from the system is in fact a series of cutter path positions. When these cutter path positions are traversed by a Numerical Control milling machine with the appropriate cutter as specified in (a) then a physical building block of physical characteristics as specified in (c) is obtained. The smoothness/ roughness of this building block is in turn related to the degree of surface finishing as specified in (b). In general, small cutter size should be used for machining small building blocks while as larger cutter size should be used for machining bigger building blocks. In order to produce building block with a high degree of surface finishing a large number of cutter path movements are necessary which might require a long time during Numerical Control machining.

It should be noted that all numerical values are in millimeters and if (a) and (b) are not specified then the values specified in the initialisation phase would be used. Building blocks created from various primitives can be retrieved in the shape operation phase by their unique identifier. For example, the first building block created by invoking the CONE primitive will be uniquely referred to as CONE1 and the subsequent building block by invoking the CONE primitive will be uniquely referred to as CONE2.

INCREMENTAL PLACEMENT AND SHAPE OPERATION PHASE

Once the building blocks have been created in the form of cutter path positions, they can be referred to by their respective unique identifiers that were assigned to them when they were created. In order words, after the creation of building block phase, a library of symbols are created and can be instanced and shape operated upon to form the cutter path positions for machining a complex engineering component.

In as far as the placement and shape operation phase is concerned, the user would instance one building block at a time by an unique identifier that is associated with it and then place it in the appropriate orientation on the x-y plane as appear on the graphical screen. When the user is satisfied that it is in the correct position, the user would then instance a second building block and position it relative to the first one. When the user is satisfied that the second building block is also in the correct position, the user would then shape operate on these two building blocks to eliminate overlapping cutter path contours. By incrementally invoking and shape operating one building block at a time the user would finally produce the cutter path contours for Numerical Control Machining a complex engineering component.

AN EXAMPLE TO PRODUCE A LEVER FORGING

The manner in which a user would interact with the proposed system is illustrated by means of an example. The aim of this example is to interactively reproduce a design as laydown in a specification drawing. This specification drawing refers to a LEVER FORGING which is illustrated in Figure 2.

In reproducing the LEVER FORGING specified in Figure 2 on the graphical screen of the Seiko-9500 and subsequently Numerical Control machining of the LEVER FORGING physical model, it is decided that 4 building blocks are to be used. This 4 building blocks are to be created from the CONE and a variation of the ELLIPSOID primitives.

In fact a hemi-sphere building block is to be created from the CONE primitive and three cylinders with ellipsoid ends are to be created from a variation of the ELLIPSOID primitive.

INITIALISATION

Photo 3 illustrates that

(a) a block of material upon which the Numerical Control machining will take place and this is an area on the x-y plane equal to 222 millimeters times 111 millimeters,

(b) the physical characteristics of the cutter size in terms of T1 and T2 as illustrated in Figure 4 are chosen to be quarter and eighth of an inch (6.35 mm, 3.175 mm) respectively,

(c) definition for the degree of surface finishing as illustrated in Figure 5 which shows the relationship between the CONE primitive, a typical cutter and the two parameters for defining surface finishing in which EPS is equal to 0.3 and EPSEDG is equal to 0.3 millimeters in this example.

Photo 6 illustrates that one building block is to be created from the CONE primitive and three building blocks are to be created from a variation of the ELLIPSOID primitive which is a CYLInder with Ellipsoid ends (CYLIE).

CREATING BUILDING BLOCKS

Photo 7 is a display of the plan view, the two side views and the isometric view of the CONE primitive. A building block can be created by simply assigning dimensions on the right hand side of the graphical screen. The resultant building block in terms of cutter path positions will then be displayed as illustrated in Photo 8 with actual dimensions as specified in Photo 7. This building block will be referred to as CONE1. Notice that the created building block is in fact a hemi-sphere.

Photo 9 is a display of the plan view, the two side views and the isometric view of the cutter path of a building block created from the CYLIE primitive. This building block is then referred to as CYLIE1. The most important point to note in Photo 9 is that the building block CYLIE1 is rotated by 90 degrees. It can be easily seen that CYLIE2 and CYLIE3 can be created in the same way as CYLIE1.

INCREMENTAL PLACEMENT AND SHAPE OPERATION

Photo 10 illustrates the placement of CONE1 within a rectangular area as defined in the initialisation phase. Photo 11 illustrates the placement of CYLIE1 with respect to CONE1 and Photo 12 illustrates the shape operation between CONE1 and CYLIE1 in which the elimination of overlapping cutter path can be easily seen. Photo 13 illustrates the final product as a result of incremental shape operation involving CONE1, CYLIE1, CYLIE2 and CYLIE3.

NUMERICAL CONTROL MACHINING OF THE LEVER FORGING

Photo 14 is a physical model produced by Numerical Control machining. The data that is input to the Numerical Control machine is infact the cutter path positions illustrated in Photo 13.

RESPONSE TIME AND ELAPSE TIME

The response time for initialisation, creating each building block and each placement is in terms of a few seconds. The response time for each incremental shape operation in this case is approximately 20 seconds.

In general terms, the response time for shape operating ELLIPSOID type building block is longer than building blocks created from other types of primitives. This is because the number of cutter path positions for ELLIPSOID is approximately three to four times more than other types of primitives.

The actual elapse time from initialisation stage to producing Photo 13 on the graphical screen takes approximately 30 minutes.

CONCLUSION

The proposed system is a low cost geometric modelling system with special emphasis on the manufacturing of engineering components using Numerical Control machine. The applicability of the system is clearly demonstrated by the LEVER FORGING example. The proposed system is a low cost system and this is clearly indicated by the hardware configuration on which the system is implemented. In as far as the user response time and throughput is concerned, current results obtained indicate that for initialisation, creating building blocks and incremental placement the typical response time is a matter of seconds. Furthermore, the incremental shape operation is also in the region of seconds except for ELLIPSOID type building blocks. Therefore, it can be concluded that the proposed system is a genuine interactive design and manufacturing system. In as far as throughput is concerned, the system is quite capable of being used to complete one or two designs per day even for complex engineering components.

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6 PRIMITIVES		variations of primitives
CONE	--	hemi-sphere vert. sharp cone vert. cylinder triangular pyramid rectangular pyramid others
ARC-BLOCK	--	typical arc-block hori. cylinder with sloping end vert. semi-disc
ELLIPSOID	--	typical ellipsoid hori. cylinder with ellipsoid ends
PRISM	--	typical prism rect. pyramid lying on one of its sides other variations
TOROID		
HORIZONTAL CONE		

Figure 1 6 primitives and their variations

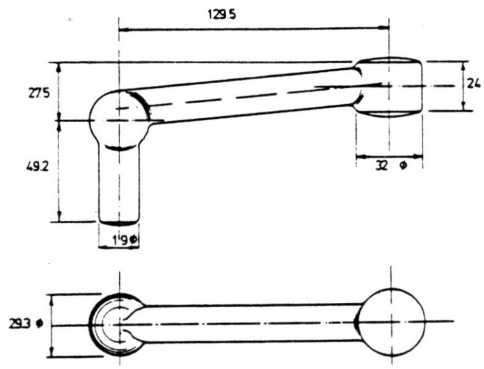

Figure 2 Specification of a LEVER FORGING

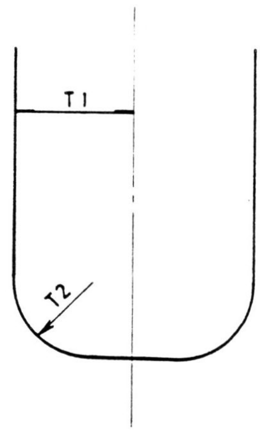

Figure 4 Cutter characteristics

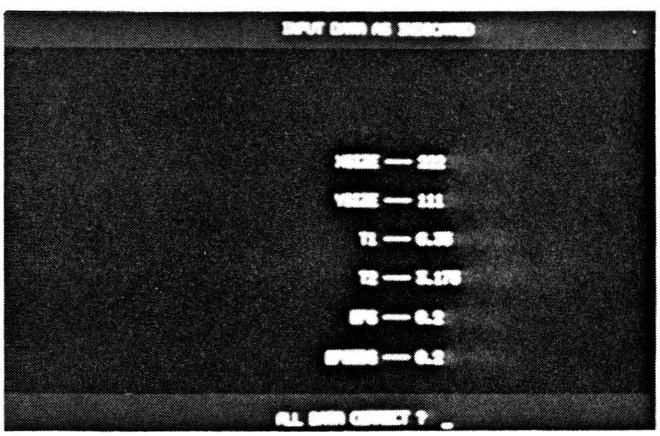

Photo 3 Initialisation of machining parameters

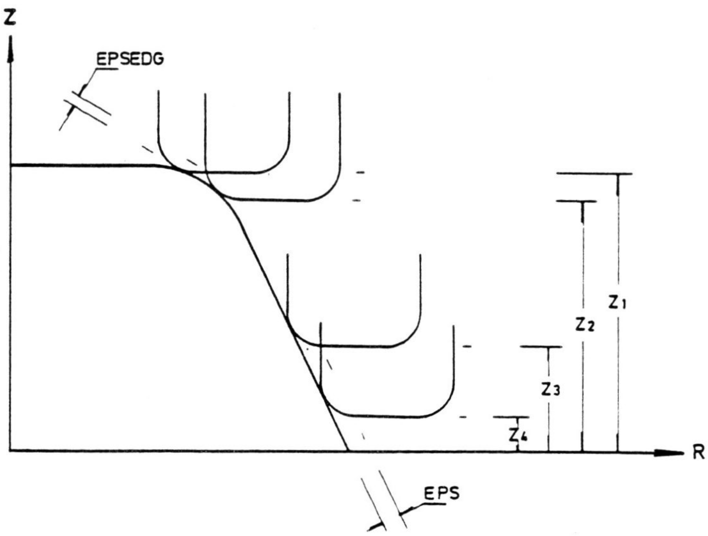

Figure 5 Surface finishing defined by EPS and EPSEDG

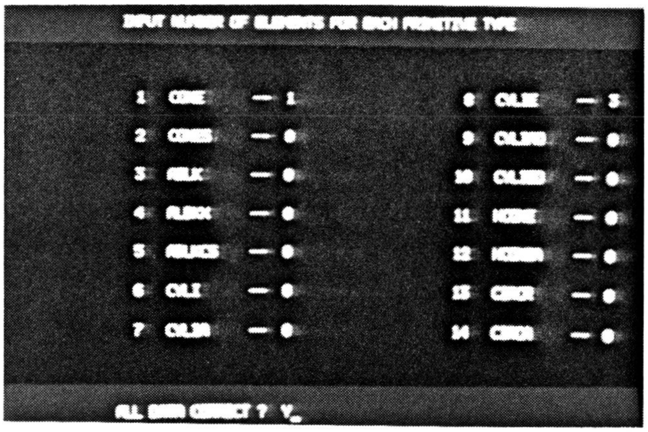

Photo 6 Creating building blocks from CONE and CYLIE

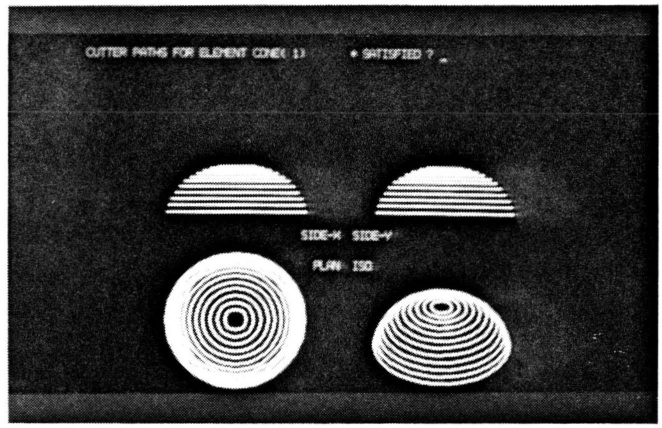

Photo 8 Cutter path of a hemi-sphere

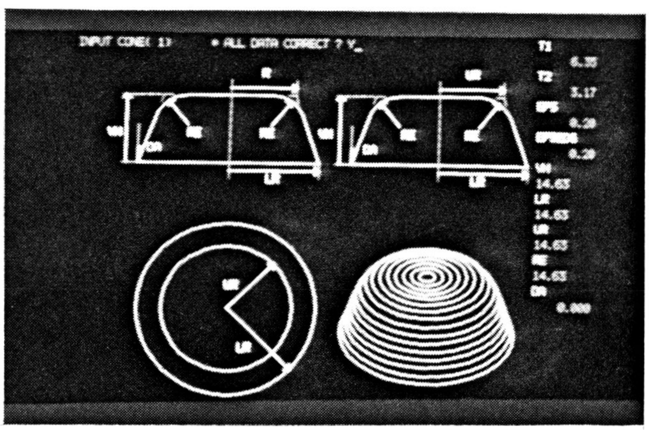

Photo 7 Entering data to create a hemi-spere

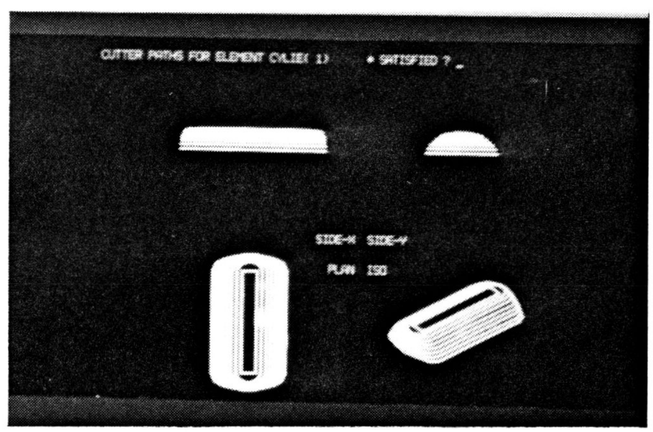

Photo 9 Cuter path of a cylinder

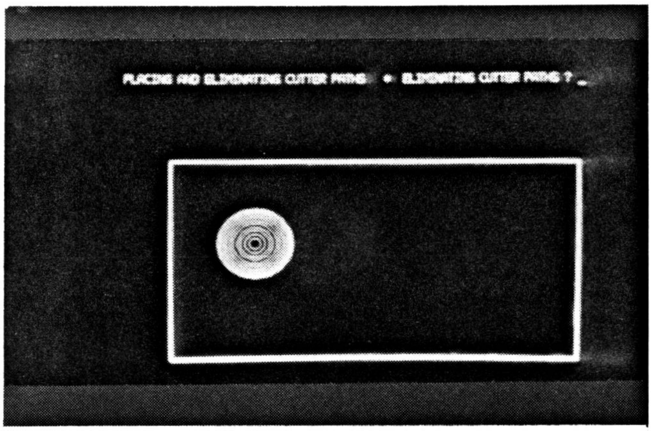

Photo 10 Placement of CONE1

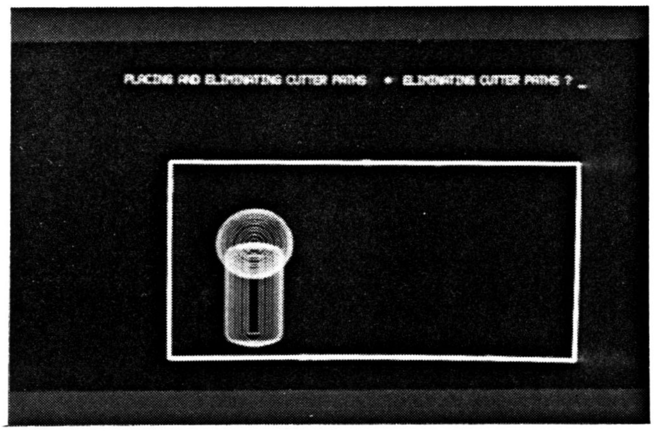

Photo 11 Relative positioning between CONE1,CYLI1

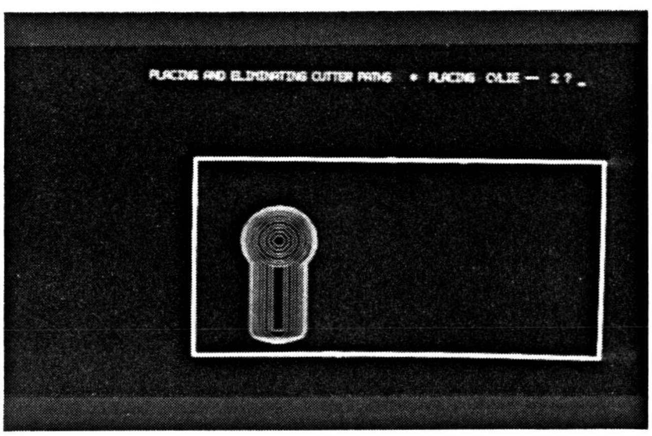

Photo 12 Cutter path elimination between CONE1,CYLI1

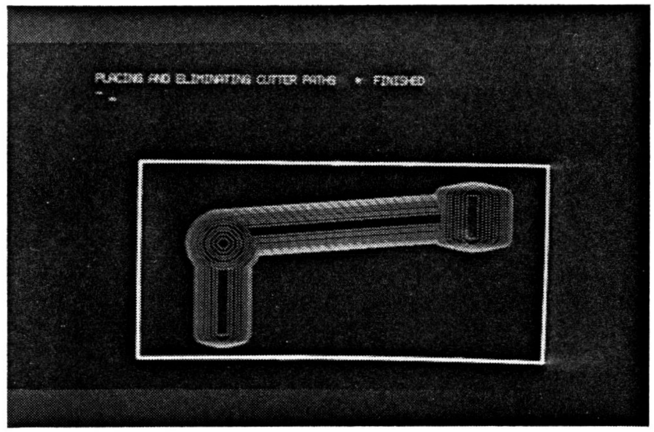

Photo 13 Final cutter path elimination

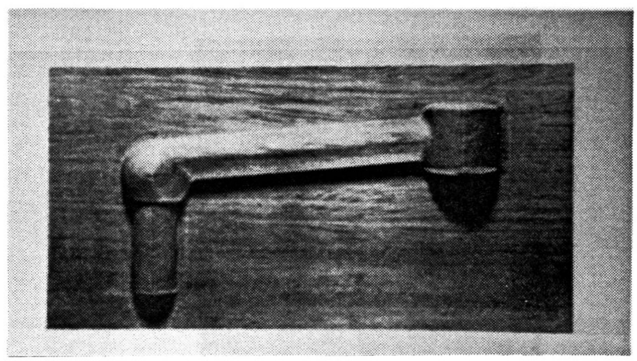

Photo 14 A physical LEVER FORGING