OXY-ACETYLENE CUTTING ....

Oxy Flame Cutting : A Computerised approach

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A programming centre software helps a programmer to generate a NC program which drives a NC/CNC Oxy Flame Cutting tool. A programming centre consists of a graphic Editor module for defining component shapes alongwith cutting parameters, an interactive/automatic nesting module for generating nest of components optimally and a toolpath module to generate toolpath for the nested shapes. Optionally the programming centre may include library management, plotting/printing and communication modules. The paper discusses different features of these modules in detail and how they can be used effectively to increase productivity.

INTRODUCTION :

Oxy-flame cutting technology has come a long way from the first generation manual hand cutting to present day's state of the art DNC large flame cutting machines. Flame cutting machines have become imperative in the industries where a large number of components are nested and cut from a large mothersheet. Before the advent of CNC/DNC technology different components are used to be cut using steel templates. The major disadvantages of template technology are the unnecessary space requirement for storing the templates, even the old ones, and the impossibility of making alternative nests out of the templates. From templates the flame cutting technology evolved by using optical scanner, which may scan a tracing paper drawing of nested components and consequently drive the flame cutting tool. This technology did not have the drawbacks of template cutting and was suitable for industries where the components were small. For cutting large components scanner technology faced a problem of trade off between workspace and accuracy. For scanning a full scale drawing the machine should occupy the space twice as large as the mothersheet size to accommodate the drawing sheet, on the other hand if a 1:4 or 1:10 scaled drawing is used (assuming the machine has the capability of handling scaled inputs) a small dimensional error in drawing is enlarged four or ten times. The scanner technology also proved to be cumbersome in preserving drawings in an atmosphere, where environmental variation does not expand or change the paper dimensions. In all the above cases, components are drawn manually and nested manually, without going into tedious alternative rest generation and possibly sacrificing a lot of tonnage as scrap. In the industries where the component mix for nest changes quite frequently either due to change in product mix (e.g. job working fabrication shops) or change in available mothersheet sizes, the production and planning department has to work overtime to generated scannable nest drawings.

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The NC technology was answer to all the above problems. A small roll of paper tape replaced the bulky drawing and thus gone the space requirement for full scale scanning. The paper tape punch contains an NC program which is nothing but an accurate step by step instructions to move the flame cutting tool in appropriate manner. The flame cutting machine becomes much more compact and the whole scanner set up is replaced by a paper tape reader and a NC controller, which thanks to development in electronics, are smaller in size every day. NC technology provides the following major benefits : accuracy, saving in storage space, speed, machine size, and easy flexibility in modification of nest. But a new bottle neck has evolved which is programming the tape and proving the tape before cutting. Even for a simple nest with large number of components, programming may become a very tedious task if started from the scratch; so the new NC controllers provide facilities like macro and looping which makes the life easier for a NC programmer. But even in NC programming nesting remains manual and hence generation of alternative nesting quickly is still a dream. Further, programming on the NC controller takes away valuable cutting time which ultimately reduces the machine utilisation factor.

The next technology is a step ahead from NC machines where a computer, either on line, integrated with the flame cutting machine, or off line aids the NC programmer generating the NC program. The aid comes in the form of a software package using which the programmer interactively draws components on the graphic screen, places components on mothersheet and thus generating alternative nest and defines toolpath for a nest. The computer generates a NC program from this toolpath, which otherwise would have been a nightmare. In this article we shall refer to such an off line software package as programming centre and try to describe its primary function in flame cutting process with respect to commercially available systems in the country and abroad.

COMPUTER : the genie behind the change

The last few years we feel the presence of computer in every aspect of our life. Though the influence of computerisation is markedly prominent in the business application areas slowly but steadily the presence of computer is also felt in the shop floor and design office applications which are in general referred as CAE (Computer Aided Engineering). Two more terms are prevalent these days, CAD/CAM (Computer Aided Drafting/Design and computer Aided Manufacturing), which can be thought of as broad characterisation of various CAE application softwares.

The industrial revolution was started by IBM, when they made a small business computer available at a unthinkable low price as a consumer item, and that ends the era of temples of electronic giants manned by computer professional speaking language as unintelligible as Martian. This new computer which is so well known as IBM/PC (Personal computer) has also triggered a new revolutions within the computer community. The standardisation of the hardware (i.e. every PC claimed to be IBM compatible) let a million programmers bloom and produce softwares of every kind, size, colour and taste. Even PC has come a long way from its initial non graphic text only screens to high resolution colour graphics which can support millions of colours. Also its processing power has increased in the order of tens by introducing more powerful processor. World is now waiting for a desk top super computer which may be commercially available within next two to three years. It is true that a non trivial CAE application necessitates more sophisticated hardware in terms of more powerful machine, mouse or digitiser as pointing device, high resolution colour graphic hardware and monitor and atleast Al size plotter and some more expensive CAE softwares. But the return is substantial and the advantages are felt within a very short period.

Programming Centre : a work station for flame cutting

If we follow the manual steps taken by a NC programmer to generate a NC paper tape from the time he receives the drawings of the components, we immediately see the scope of a programming centre. The similar steps are followed by a programming centre and having a fast processing power it manages to introduce one or two itrative loops which were not practical when done manually.

The most basic programming centre must have the following features either as separate modules/programs or sometimes more than are features merged together in a single module :

1) A component drawing aid, most probably through a graphic interface.
2) A 'library of components' management module.
3) An interactive nesting module.
4) A toolpath definition module.
5) NC program generation module.

Optionally a more sophisticated programming centre may provide the following extra features :

6) An automatic nesting module.
7) An automatic toolpath generation module.
8) A plotter/printer module to plot the nesting and individual components.
9) A communication module for transmitting the generated NC program to a paper tape punch machine, to the NC controller directly or to a datalogger.

We shall discuss each of the modules in more detail in the following sections.

Apart from the dedicated programming centre for profile cutting machine (which may be used for any kind of profile cutting technology e.g. Oxy-flame, plasma, laser, water-jet) also some generalised NC programming softwares are available for wide range of machine tools like milling, turning, boring etc. It is found that the generalised NC softwares are not equipped enough to incorporate special technological requirements of profile cutting machines and a dedicated programming centres are more flexible in handling special ☞

requirements like lead in/lead out, thickplate cutting, pierce point optimisation, powder and punch marking.

A typical programming centre hardware consists of the following hardware items :

1) A computer having at least 16 bit CPU and preferably a numeric co-processor for fast number crunching.
2) High resolution (at least 640 x 350 pixels) monochrome or colour graphic capability.

   A monochrome monitor is sufficient though a colour monitor provides a better working flexibility.
3) Minimum of 1MB on board memory.
4) 40 MB hard disk.
5) mini or micro floppy disk.
6) A good dot matrix printer with graphic capability.
7) A two/three button mouse.

OPTIONALLY

8) A multipen plotter of minimum A3 size.
9) Digitizer of minimum A3 size.

PROGRAMMING CENTRE : more than the sum of its parts

The different functional units of a programming centre may be available as independent programmes and one may assemble a programming centre out of these standalone programs. But an assembled programming centre lacks the power of integrated one since each unit is not aware of the existence of the other units. We shall see shortly that each unit must be fine tuned to the requirements of other units.

GRAPHIC EDITOR

This is the entry module to programming centre, using which the user interactively defines a component shape. A graphic editor acts as an engineering drawing processor in the same line as a word processor acts to textual document. But unlike word processor the basic entities of manipulation are straight lines and circular arcs. Like word processor these entities may be inserted in a drawing, placed anywhere, moved, copied blocked together. Each of these entities may be drawn different ways as the case may be. For example an arc may be drawn by specifying centre, radius, starting point, end point and direction or by specifying three consecutive

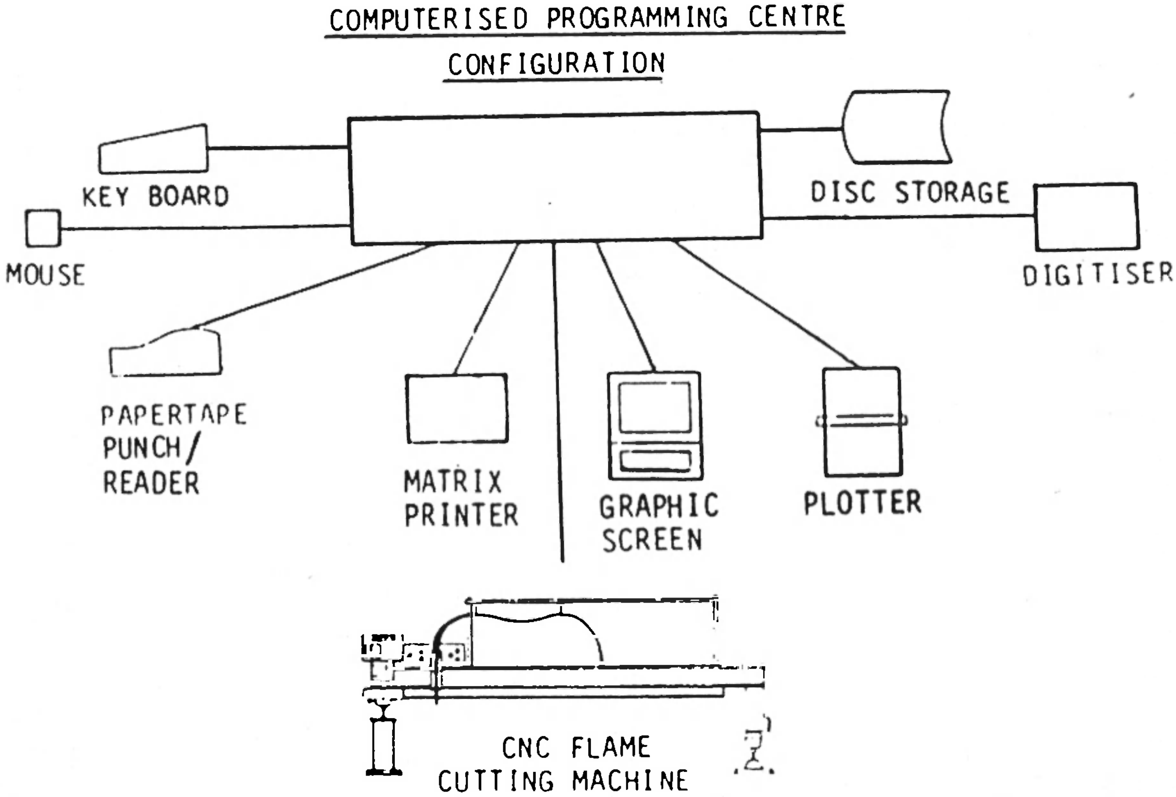

Fig. 1 : A typical configuration of hardwares for programming centre

points or by specifying a line and another tangential arc. Computer calculates the dimensions of an entity to an accuracy which far surpasses the tolerance of the machine. A component shape drawn by graphic editor guarantees the dimensional accuracy much superior to the best draftsman in the world. It also gives a unthinkable power to draw a complex shape like gear where the user draws single tooth pitch, defines that as a block and repeats this block number of times to draw the complete gear.

To help detailing for a large shape within the confinement of small screen, graphic editor provides different viewing commands like zooming to unlimited precision and panning. Some graphic editor also provides text writing features which either used to annotate a drawing, to write dimensions or may be used as a portion of the component to be marked by powder marking tool during cutting.

Some graphic editors provide features to define different cutting parameters attached to a component. These cutting parameters may include cutting directions for different contours, kerf/compensation amount, lead in/lead out distances etc. Also it is possible to define lines/arcs to be powder marked or punch marked.

A defined shape is stored in disk files for later use. Here the programming centre packages differ considerably, some of them store each shape in a single file or a programming centre which has a library management module, may store a number of shapes in a single file called library. For library oriented programming centre it is possible to attach various MIS information to a shape like component name, material, thickness, order number, customer name or whatever an organisation thinks is important. User inputs this MIS information for each newly defined shape when he saves this shape in a library. A library manager/graphic editor can add some more geometric information about the shape like area of the shape, cutting length, powder marking length, punch marking length.

The function of graphic editor ends by defining shape and saving it either in a single file or in a library with or without MIS information.

A 'LIBRARY' MANAGEMENT MODULE

A library contains the geometric and cutting information of a shape alongwith other MIS information. The library management module manipulates each shape as a single entity and transfer shapes from one library to another and let the user change different MIS information about a shape. It is also used within nesting and automatic nesting module to select shapes from one or more libraries for loading. The selection can be made by using complex criteria like "select shapes with material ST42W and thickness less than 20 mm and the orders which has a due date not later than 20th May". Provided the library has the information about shape material, thickness, order due date, the library management module selects the shapes from the marked libraries, who satisfy the criteria.

For any organisation using large number of shapes for different products or jobs, library management plays an important role to manage the shapes efficiently.

AN INTERACTIVE NESTING MODULE

Using an interactive nesting module user defines dimensions of a mothersheet, loads shapes to be nested from libraries and manually places these shapes on the mothersheet. Interactive nesting module aids the user in dragging the component anywhere on the mothersheet rotate it to any angle and mirror it. It also provides a fast way to place more than one components of the same shape by repeating it number of times in X and y directions. One of the primary requirements of a nest is to keep a minimum clearance between two components and between a component and mothersheet edge. Amore sophisticated nesting module does not allow user to bring two components closer than the minimum clearance. So it continuously checks the distance between two components. Other nesting module has utilities to check whether one or more pairs of components satisfy the minimum clearance condition.

For common cut between two components, nesting module must override minimum clearance condition. Not only that, it must keep information about this common cut entities, because at later toolpath generation stage only one cut path is generated rather than two.

The interactive nesting module continuously tracks the utilisation factor as the user adds more and more component on the mothersheet or deletes a component from the mothersheet. This online display of the utilisation factor lets the user control his nest for maximum utilisation. ☞

AN AUTOMATIC NESTING MODULE

When the computer places components on the mothersheet for achieving good utilisation satisfying minimum clearance condition, automatic nesting module is at work. One misconception is prevalent in the industry that, an automatic nesting generates an optimal solution i.e. a nest with maximum utilisation. But as a human operator never knows whether he has reached the best nest or there is no room for any better utilisation, computer also never knows for certain whether it has reached the optimal solution even if it works for hours and days untiringly. Unlike linear programming of operation research there is no mathematical model for nesting with generalised arbitrary shapes. These types of problem in computer science is called a **NP Hard problem.**

As a problem, automatic nesting is itself very interesting to computer scientists and a fool proof method is yet to be discovered. All the commercially available automatic nesting softwares tries to mimic the human way to place components. For that they use different empirical methods or **heuristics** which do not have any mathematical proof but found to work well to yield a good utilisation factor. For example one heuristic may be to place larger shapes first and smaller ones later. But in one case it may be found that if one placed a certain smaller shape before a larger one it would have given better result. Also each automatic nesting module may use higher level of 'try' to place shapes, which means it takes more time to place components and hence the chances of greater utilisation is better.

Some more sophisticated automatic nesting module can place components in the internal holes of larger components.

The normal industry practice is to fine tune a nest generated by automatic nesting by which the utilisation may be increased by 2% to 5% more. A computer generated nest can have utilisation factor as large as 95% depending on the relative size and shapes of the components. It is always advisable to mix the components of various sizes in a single nest and to use some small regular shapes for filling up nooks and corners.

Fig. 2. shows a typical out put generated by an Automatic Nesting Module.

A TOOLPATH GENERATION MODULE

The toolpath generation module is responsible for defining pierce point, lead in/lead out for each components on a nest and the order of components to be cut. For interactive toolpath generation module user defines the order in which contours are to be cut alongwith pierce point for each contour. The module automatically inserts lead in/lead out of various types (like linear, tangential arc, angular) before and after the contour. It also inserts rapid traverse between two pierce points. To minimize number of pierce points user may follow continuous cuts between external contours. Especially for thick plates where automatic piercing is not possible continuous cutting is followed between external contours. For internal cuntours toolpath generation module

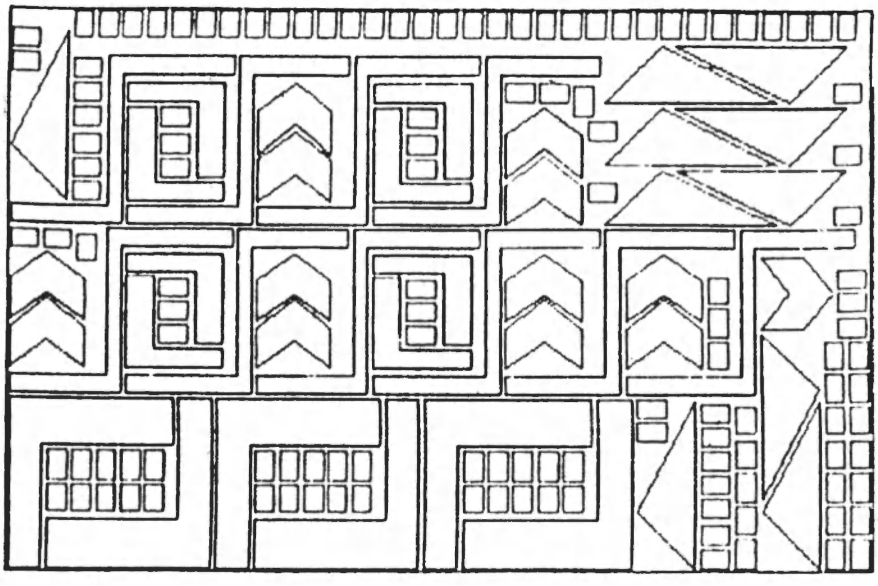

Fig. 2. shows a typical out put generated by an Automatic Nesting Module.

should be able to cross mark each pierce point by powder marking so that operator may drill a hole at those points before starting the actual cutting.

Toolpath module is also able to mix and interchange marking and cutting to minimize rapid transverse and thus reducing cycle time. An online display of total cutting/marking length and rapid traverse length let a user change the order of components to be cut to reduce rapid traverse length.

An automatic toolpath generation is almost as difficult as automatic nesting. Here the objective is to generate a toolpath such that the total rapid traverse is minimum. The problem is known as the Travelling Salesman problem in computer science. But auto-toolpath generation becomes more complicated due to the fact that the components can not be cut any arbitrary order since always an internal hole is to be cut before its external contour and preferably contours with smaller areas are to be cut before those with larger areas. To reduce mechanical distortion a bridge is defined between two components and when toolpath is generated, it joins two bridged contour into one.

Most of the programming centres generate NC controller code from the defined toolpath in this module. The standard NC controller language like ESSI or WADR are used, and may be fine turned for a particular controller. The output is always a text file which may be transferred to the controller by various methods.

OTHER UTILITY MODULES OF A PROGRAMMING CENTRE

Plotting of drawing

Most of the programming centres can plot an individual shape, a nest or a toolpath either on a dot matrix printer or plotter. Also it is able to generate production planning information about a nest for which toolpath is defined. The planning information may contain the identification of each component on the nest, total cutting path length, total rapid traverse length, number of pierce points. Also knowing the cutting and rapid traverse speed it can accurately estimate the total cycle time.

COMMUNICATION TO CONTROLLER

For communication between the programming centre and the NC controller either of the three standard procedures may be followed :

1) Using a paper tape punch with the programming centre to generate NC paper tape and a paper tape reader with the NC controller to read that tape.

2) Using a battery backed portable data logger to which NC program is transmitted using serial R.S - 232C communication link from the programming centre. Again the same program is transmitted from datalogger to NC controller using serial R.S - 232C communication link.

3) A direct R.S - 232C serial link between the programming centre and the NC controller. If the distance is more than 50ft. then the connection may be boosted either using line driver or by using modem and normal telephone line depending on the distance. The communication line must be well shielded to avoid stray industrial noise due to high current flowing equipments like welding machines or plasma cutting machines.

4) If the NC-Controller has a micro-Floppy drive (of 3.5" size) and be able to read IBM-PC files, then the NC programs generated by Programming Centre may be transferred using micro-Floppy. This is one of the easiest ways of communication.

PROGRAMMING CENTRE : Future

As the hardware price vs. performance index goes down and new software tools are developed, programming centre becomes more and more powerful. A major change in programming centre will be reflected in terms of user interface. The future will see the Graphical User Interface (GUI) as a standard for user interfaces for all major CAE products including programming centres and this standardisation will cut down the training cost for the users considerably. The use of Artificial Intelligence and Expert System will give a programming centre more power in terms of better automatic nesting and automatic toolpath generation modules. A standardised network of computers and CNC machines will make a consistent use of information without redundancy. ■