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A SPECIAL-PURPOSE LOW-COST EXTERNAL TURNING PROCESSOR FOR NUMERICAL CONTROL (N.C.)[1/]

by

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This paper describes a processor program developed by The Machine Tool Industry Research Association to make it possible to turn economically under numerical control single components of complex contoured form.

Introduction

Programming is probably still the least satisfactory aspect of numerically-controlled machine tools although it is also the aspect to which most development effort has been devoted. Simple components present few problems but for any but the simplest shapes some form of computer assistance is virtually essential — and this is where the trouble starts. There are plenty of processor programs available for use by the part programmer — and, indeed, this is one of the problems as it is difficult to know which to choose for a given application — but there are still many situations in which none of these programs makes it possible for N.C. turning to compete economically with manual turning. This is especially the case when only one or two of a particular contoured component are required; the cost of using suitable processor programs for the preparation of a machine control tape is prohibitive and the simpler programs are unsuitable. It is in order to make it possible to produce single complex turned parts economically on N.C. lathes that M.T.I.R.A. has developed yet another processor program, a brief description of which is given in this paper.

The program was originally developed to make it possible to manufacture by N.C. sets of rolls for cold roll-forming machines that had already been designed by C.A.D. A typical set might include 40 rolls — see Figure 1 — all different and only one of each set will usually ever be required. The program is, however, also suitable for other turned components required in one-off or small numbers.

Specification

The M.T.I.R.A. processor has been written to make it possible to produce any given externally-turned form with a limited library of tooling. It was decided at the outset that what was required was a processor that would accept information about the geometrical form to be produced and would then automatically produce a complete control tape for any specified machine tool/contral system combination; the part programmer should not have to do anything other than define the shapes of the blank and of the component to be produced. It was regarded as essential that the time spent by the part programmer should be kept to a minimum and that data which had been generated by a design program should be directly usable as input. The computer cost should also be small. In the event, all these aims have been achieved, the part programming effort required for a batch of components is less than that required with one of the more general-purpose cammercially available processors and the actual cost of computing, which up to now has been undertaken in-house on a small computer (32K store), is much less than the charges which would have been incurred on bureau machines.

There is na breakdown of the program into processor and post processor and, in order that the correct format for the part-program tape shall be produced for the particular N.C. lathe to be used, some of the machine and control system requirements are built into the processor and some are provided as input data. Thus a version of the whole processor is required for each lathe for which N.C. tape is to be produced. This is not a limitation as an experienced FORTRAN programmer can readily modify an existing versian ta produce a new version in less time than it takes to write a post processor for an existing processor/machine combination.

There are therefore two distinct groups of data which have to be provided for each application. Because of the way in which the program operates the first group of data need only be input once for a complete set of components defined by groups of the second type of data.

The first group of data comprises:-

(i) Information about the control system, the lathe and the accuracy to which the part program should be calculated on the computer.

(ii) Particulars of the tools to be used, including geometrical information and specific codings relating to the selection of tools on the machine.

(iii) The cutting technology, i.e. feeds, speeds, depth of cut, number of finish cuts and the order in which the selected tools are to be used.

The second group of data is a definition of the geometry of the component to be cut.

Features of the new processor

Different machines and control systems usually have different operating features and require part-program tapes of different format. The processor is so written that many of these differences can be input as data rather than by making changes to the processor program itself. For example, the programmer can indicate, by in-putting appropriate digits, whether absolute or incremental programming will be used, whether the centres of arc movements will be defined in absolute or incremental terms and whether any plus or minus sign will be given with these values. The programmer will also state as data the length of each address code — up to 12 labels are allowed — N, G, X, Z etc. He can also state whether constant cutting speed and constant feed/rev facilities will be used(if these are available on the selected machines). Information relating to the accuracy to which the part program is to be computed in order to avoid tool/workpiece collisions is included at this stage also. Tool-change and tool-resting positions are put in, as is the maximum rapid traverse rate to be allowed. Information is given relating to the maximum spindle speed, the speed at which maximum power is achieved and also the power required for a given volume of metal removal per minute so that allowance can be made for reduced power at reduced speed and appropriate modifications made to the feed rate within the computation. If constant cutting speed is not possible on the selected machine then a table of spindle speeds against the S code is also required.

Tooling

The processor has been developed primarily to produce control tapes for sets of non-identical components of the same general type. Tooling and machining conditions are defined for the set as a whole, although not all the tools will necessarily be required for each component.

Area clearance (roughing out) around the convex parts of a component does not present a tooling or computing problem but the clearance of grooves and concave areas presents tool-access problems when using standard turning tools — and work for the computer in remembering which parts of the blank material have already been removed.

These problems are exacerbated if roughing cuts within concave areas are made by conventional turning and it was, therefore, decided to cut in concave areas by grooving and facing operations using deep-grooving tools of the type shown in Figure 2. As a result, all roughing cuts can be made with a library of just four tools — left-hand and right-hand turning tools and left-hand and right-hand grooving tools. The technique used is illustrated in Figure 3. (A recently introduced parting-off tool can replace both grooving tools and thus allows all the grooving and facing area-clearance cuts to be made with a single tool.)

Finishing cuts are made using single-radius contouring tools of which any number may be defined, of either hand and of any radius. The order in which the tools are to be selected is given as data for each finishing cut and, once a tool is selected, all the work for this tool is programmed before it is changed for the next. The processor selects the first tool to be used and produces control tape for as much of the profile as can be cut with that tool. If necessary, other tools are then selected in the defined order until control tape for the whole profile has been produced.

The geometry of the tools is effectively defined by a series of straight lines and these lines are used by the processor in checking for and avoiding tool/workpiece collisions. These interference lines are defined by stating the co-ordinates at the end points and also by defining the slopes of the lines and their extrapolated intersection with the Y axis. Although some of this information is redundant it is expedient to provide this amount of detail in order to minimise the work undertaken by the computer and thus minimise storage requirements. Figure 4 shows how an interference line for a radiussed profiling tool is defined, the information required by the processor being given by the values of tan Θ, C, x_1, y_1, x_2, y_2. By referring to the figure it can be seen that all these values can be calculated from w (the width of the tool plus a safety margin), r (the radius of the tool tip) and Θ (the angle the line makes with the X axis). Other configurations of tool are dealt with in a similar manner and as many lines as necessary to determine possible interference between tool and workpiece can be defined.

If it should happen that parts of the profile cannot be cut with the tools available, the processor prints out a warning message but continues to produce control tape for any remaining finishing cuts. In its present form the processor deals only with external turning and has no provision for threading, drilling, boring or undercutting. It will, however, eventually be extended to include these operations which, in the meantime, can be added to the control tape manually if they are required.

It is not necessary to produce a complete N.C. tape for each component in one operation. Tapes for area-clearance turning, area-clearance grooving and each finish cut can be produced separately if necessary and this technique does enable the system to run on a comparatively small computer. There is also often an advantage in N.C. turning in being able to return to a specific point in the part program if required and this is not always easy unless properly defined start and finish blocks are included in the part-program. The preparation of part-program tape in separate sections does ensure that these desirable program stops are available.

Cutting data

This describes the feeds and speeds to be used with each of the cutting tools for different materials, together with the depths of cut for roughing and finishing. Also included is the order in which the finish tools are to be selected as required.

Workholding

The processor was originally written to produce control tapes for turning rolls held on a mandrel and supported by a tailstock, thus allowing turning both towards and away from the headstock. It is, however, also suitable for use with components held in a chuck or to be turned from bar and in these cases only tools which cut towards the lathe headstock would be programmed.

Component data

The processor was originally developed to operate with component data generated by a computer program for the design of rolls for roll-forming machines. It will, however, accept data prepared manually as shown in Table I for the example given in Figure 5. It should be noted that this is the only information that the part programmer will normally have to prepare.

As an alternative, data can, if preferred, be presented in polar coordinates.

Tape checking

As the aim of this processor is to make it economic to produce non-repeating one-off components by N.C. it is obviously undesirable to have to waste machine time in trying out tapes. A tape-checking program has therefore been written which uses the control tape as input data and displays the cutter path on a visual display unit — see Figure 6. Checking a tape in this way takes only about one minute and any major errors are readily seen.

A further program which can be used if desired produces an accurate dimensioned drawing of the finished component on a graph plotter.

Cost

Once a version of the processor has been prepared for the particular machine tool/control system combination to be used (versions currently exist for the Dean, Smith & Grace 500TC lathe with a UMAC control system and for the Swedturn 10 lathe with a CNC system) and a basic library of tools and cutting conditions has been defined, the use of the processor for the manufacture of a component involves only:

a) defining the tools and the cutting technology to be used;

b) defining the geometry of the component and the blank from which it is to be made.

The time required for producing the required information depends upon the complexity of the component but is typically about 15 minutes. Computing charges for preparation and checking of the control tape for one component amount to about £5.

Application

This processor program was developed to facilitate the production, by N.C. turning, of sets of rolls for roll-forming machines — see Figure 1. The time to design a set of rolls for a particular component had already been cut from a week to two hours by the development [1,2] of a computer program for roll design which also reduced the cost of this work by a factor of about 4. The processor program enables the manufacture of the rolls to be carried out by N.C. at a cost which will usually be less than the cost of manual turning and which allows the manufacturing time to be reduced from typically half a day to 20 minutes per roll.

The alternatives available for part-programming the components for which this processor is applicable are either manual programming or the use of one of the commercially available processors via a computer bureau.

Because of the complexity of profile which is met in the field for which the work was initially undertaken it could take a manual programmer about 3 days to produce an error-free version of a part program for each component and, in general, this would make N.C. turning uneconomic compared with turning on a manual lathe.

The second alternative is to use one of the general-purpose turning processors (e.g. MITURN[3]) on a bureau system. Although these processors will carry out many more operations than the special-purpose processor described here (threading, boring, under-cutting, introduction of form tools) they are less automatic in use. The part programmer normally has to divide the machining involved into specific areas and to define how and with which tool in an available library each area is to be dealt with. Present studies indicate that at least one hour of part-programming time is needed for each component over and above the time he has to spend in bringing the initial design data to usable form. In addition, computer costs of about £20 per component are also incurred. The turn round can be anything between 2 hours on an on-line system and a week by post off-line. These times and costs have been arrived at by a study of EXAPT, NELAPT, MITURN and COMPAC II, all of which give a somewhat similar result. In addition, it is necessary in some instances to pay a standing charge for the use of some of the commercial systems. It can, therefore, be seen that use of this special-purpose processor is highly competitive for producing part-program tapes for components of the type for which it is written and, indeed, that on economic grounds it is the only real challenge to manual turning for small-quantity production.

References

1. A. Rhodes, T. Munro and A.S. Boardman
Computer-aided design and manufacture of rolls for cold roll-forming machines
Proc. 16th International Machine Tool Design and Research Conference, Manchester 1975: Macmillan: London 1976.

2. J.J. Marklew
An important job for the computer in cold roll-forming.
"Machinery" 9th June 1976.

3. TNO MITURN - a programming system for N.C. lathes
Machine Tool Research Vol. XII No.2 April 1973.

Table I

Data sheet in cartesian coordinates for the component shown in Figure 5

Unit selection (all units must be consistent)

For inch input and inch output enter 1

For inch input and mm output enter -1

For mm input and mm output enter 2

For mm input and inch output enter -2 | **-2**

Component identification number (up to 5 digits) | **1**

Blank length | **164**

Blank diameter | **108**

Radial distance of start point from the axis of rotation | **24**

Specification of X (longitudinal) and Y (radial) coordinates of the end point of each element of the component in a clockwise direction

Three items of information are required relating to each element in turn

Item I X coordinate of end of element. Datum is the extreme left hand end of the component

Item 2 Y coordinate of end of element. Datum is the centre line, or axis of rotation

Item 3 For a straight-line element is 0

For an arc is its radius with the appropriate sign

For an anticlockwise arc, radius is positive

For a clockwise radius is negative

Element No.	Item 1	2	3
1	28	24	0
2	28	50	0
3	48	50	0
4	48	30	0
5	58	20	10
6	88	20	0
7	96	24	10
8	164	17.44	-40
9			
etc			
First terminator	-999		

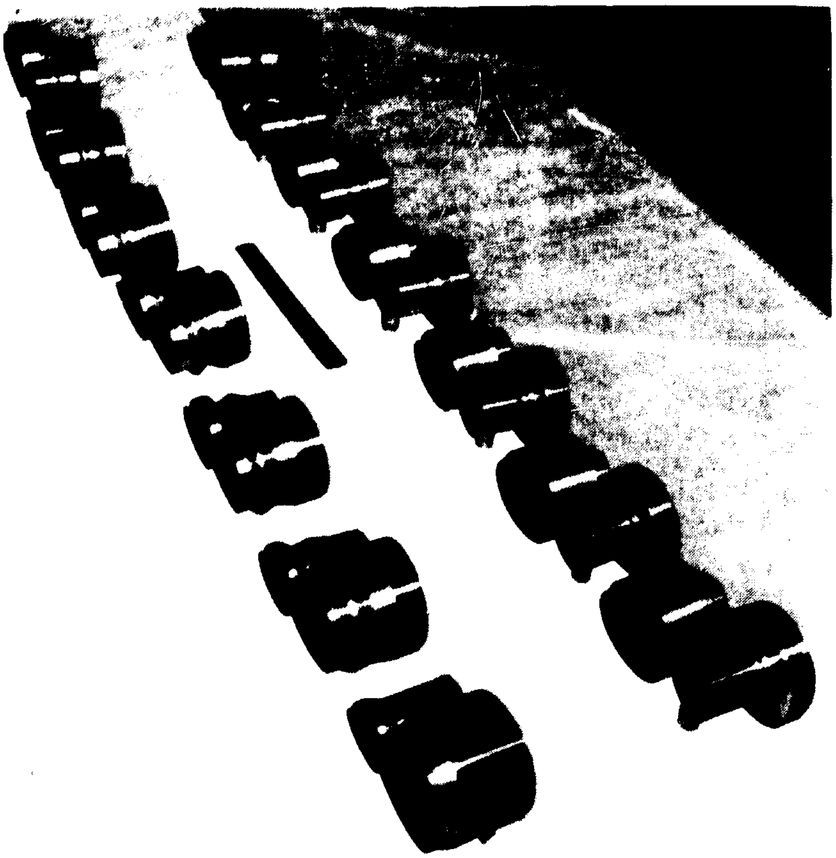


Figure 1. A set of rolls manufactured using the processor described in this paper.
(Courtesy: The Oliver Machinery Co. Ltd.)

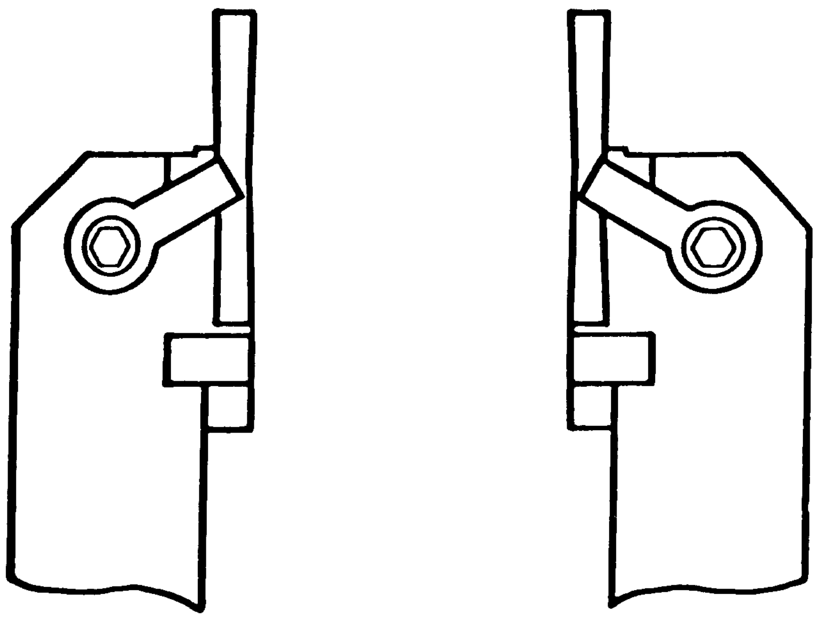
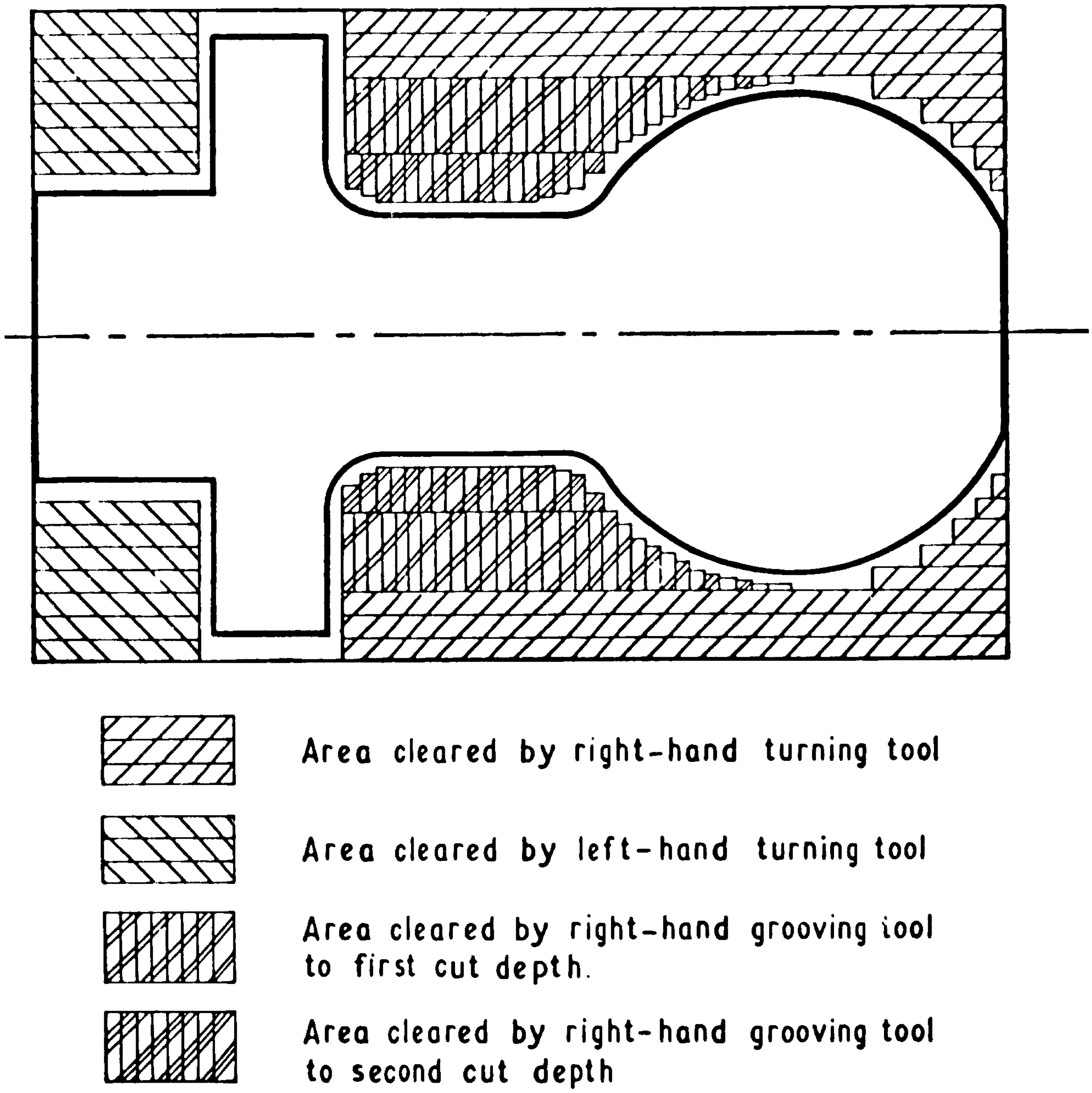


Figure 2. Deep-grooving tools as used for roughing cuts.



(Left-hand grooving tool not used for this particular component)

Figure 3. Area-clearance routine for a convex/concave component

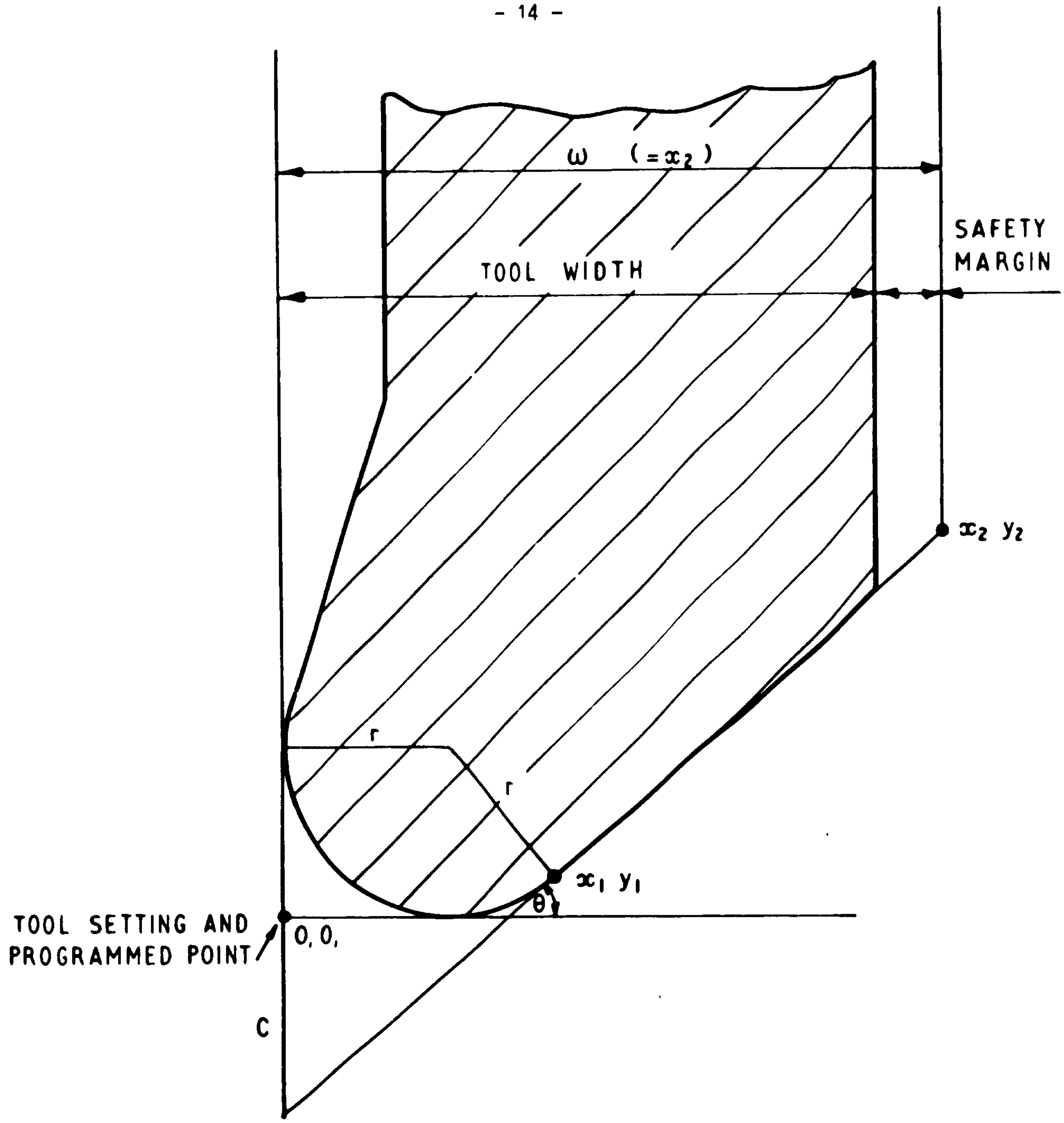


Figure 4. Definition of interference lines on a profiling tool.

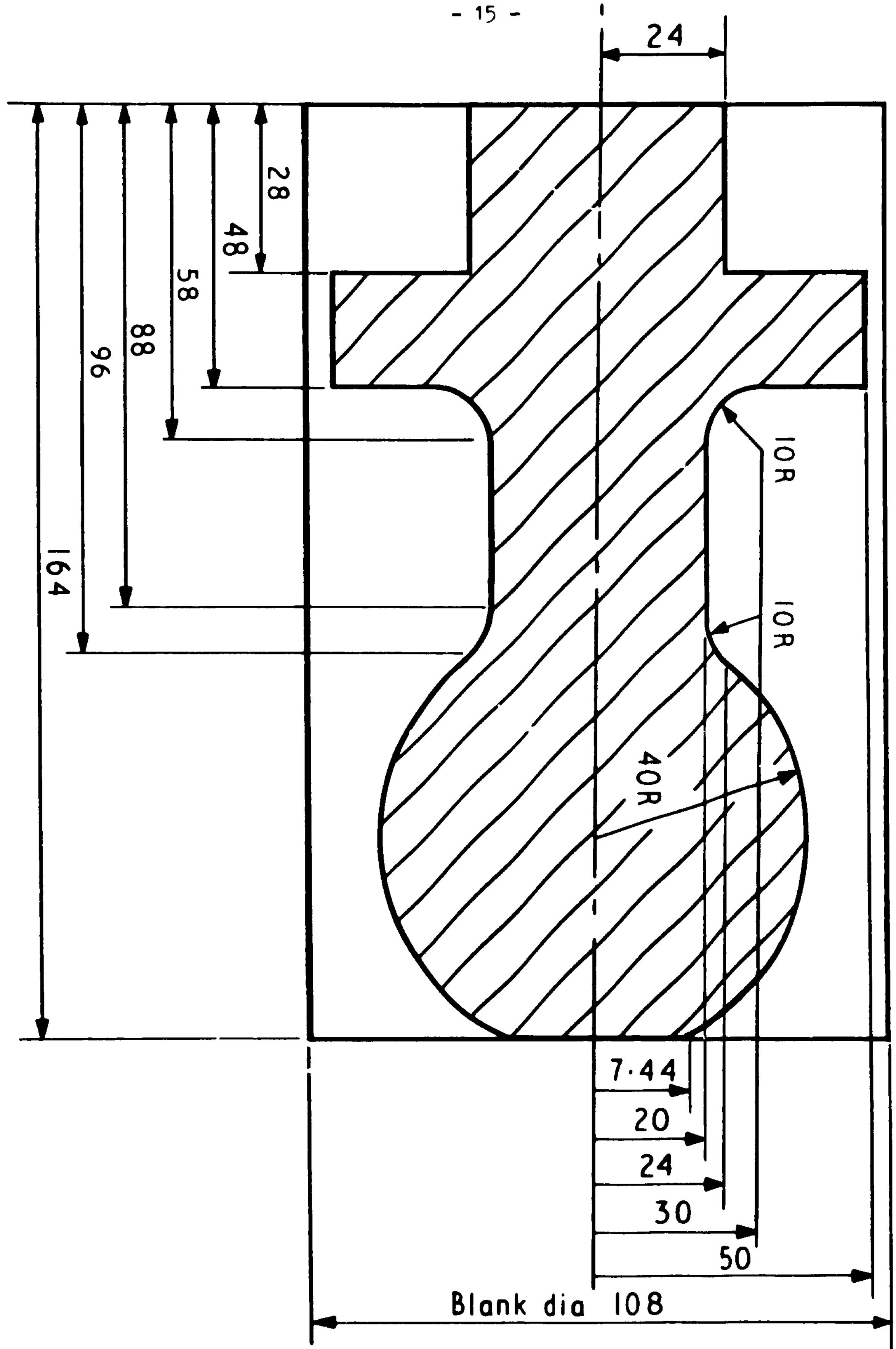


Figure 5. Component dimensioned in Cartesian coordinates.

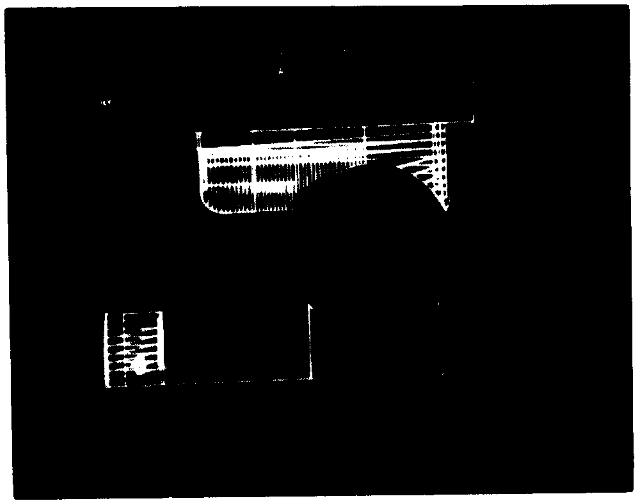


Figure 6. Tape check on visual display unit.

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