COMPUTER – AIDED – DESIGN OF WORKHOLDING DEVICES*

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ABSTRACT

This paper describes a CAD system used for workholder design. The interactive system can be used to generate the best location system for a workholder and also assist with the positioning of supports and clamps in order to minimise the influence of the machining forces.

INTRODUCTION

The function of a workholding device is to ensure that workpieces are consistently held in some definite relationship to the cutting tool during the machining process despite variations in the stock dimensions and in the operator skill. The workholder must maintain the positional relationship of the workpiece with the cutting tool during machining, despite the action of the various forces, namely the cutting forces, the clamping forces and the workpiece weight. In addition, the workholder must restrict the deflection of the workpiece under the action of the forces by means of carefully positioned supports. Workholders also have practical requirements: ease of swarf removal, run through for cutting fluids, quick action clamping and many others. A summary of these practical requirements is given in the Production Engineering Data Memoranda titled Jig and Fixtures Design[1].

This paper outlines an interactive computer-based system used for the design of precision workholders satisfying the above requirements. Interactive computer-aided design has several advantages for this application. One of the main advantages is that the experience and knowledge of the designer can be effectively combined with the information processing capability of the computer.

The programs were developed using the Science Research Council computer facility at the University of Manchester Institute of Science and Technology. The

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visual display units used were a Tektronix 4010 storage tube and an Imlac refresh display.

For hard copy, a thermal printer was used and recently a Benson plotter has also been added to the equipment. The computer language used was Fortran, together with GINO-F[2] for the graphics.
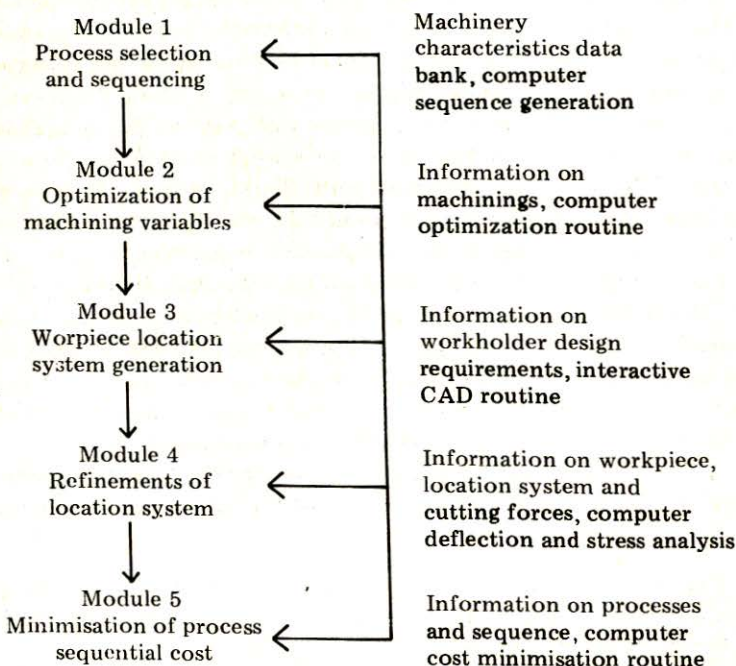
WORKHOLDING DESIGN PROCEDURE

The design of a suitable workholder involves the positioning of locators, supports and clamps on to appropriate workpiece surfaces. The function of the three elements is defined below: —

The locators — defines the datum point, line or surface datum
The supports — restrict workpiece deflection during the machining process.
The clamps   — hold the workpiece in a defined position against the locators during machining.

When the interactive system is used the designer sits at the computer terminal and folows a pre-defined procedure. He works in a stepwise manner through a set of modules which are shown in Figure 1. The precise order of progress through the modules is shown in Figure 1 and is described in more detail below: —

Figure: 1
The Modules which were developed for the computer-aided
design procedure of workholding devices

Module 1
Process selection
and sequencing
→ Machinery
characteristics data
bank, computer
sequence generation

Module 2
Optimization of
machining variables
→ Information on
machinings, computer
optimization routine

Module 3
Worpiece location
system generation
→ Information on
workholder design
requirements, interactive
CAD routine

Module 4
Refinements of
location system
→ Information on workpiece,
location system and
cutting forces, computer
deflection and stress analysis

Module 5
Minimisation of process
sequential cost
→ Information on processes
and sequence, computer
cost minimisation routine

Step 1: From geometric definition on the screen the critical surfaces and dimensions can be identified. The production planner can specify processes for component manufacture using a data-base of information about machining capability available to the concern. The tolerance chart and use of group technology in process planing are useful in that the manufacturing sequence required to produce the component can be defined and the need for special tooling or workpiece holding devices can be identified.

Standardisation and simplicity in the design is an important factor to reduce complexity and enable high production rates. Significant consideration in the design procedure must be given to determine if the workholder can be made from standard off the shelf components available in the concern or similar workholders have been designed before. If there has been previous designs, or the components are available commercially, then there is no need to carry out the full design procedure of a new device.

Step 2: Using the CAD system the machining feeds, speeds and depths of cut must be determined. There are several ways of entering this data into the system. It can be directly inserted at the tolerance chart construction stage by the designer. Alternatively there was provision to use the non linear optimisation technique Geometric Programming[4] to evaluate the machining variables for single and multi-pass metal cutting. Experimental data stored in the data-base is used and the basis of the evaluation are the values of depth, feed and speed to minimise the machining cost.

Step 3: Depending upon the overall shape envelope of the component a location system can be selected. The main principles for this have been defined by Eary and Johnson[5]. The computer system provides information to the designer that assists in the selection of the best location system. It does this by providing information on the location systems for simple prismatic parts by checking that there are no redundant locators. However, the system provides information to the designer and the choice of locators is controlled by the designer.

Step 4: Tentative positioning of clamps and supports can be made. The selection of clamp type and support type is made from a standard menu of stored clamps and supports. The designer can then position these entities around the component. The Finite-Element-Analysis package[6,7] was used to examine workpiece deflection under the calculated machining loads. Using the Finite Element Analysis the clamps and supports can be positioned to minimise deflections.

All the programs were developed using the SERC Interactive Computing Network link in the Control Engineering Department of the University of Bradford. The Department is directly connected to the SERC Prime Computer site at UMIST (University of Manchester Institute of Science and Technology).
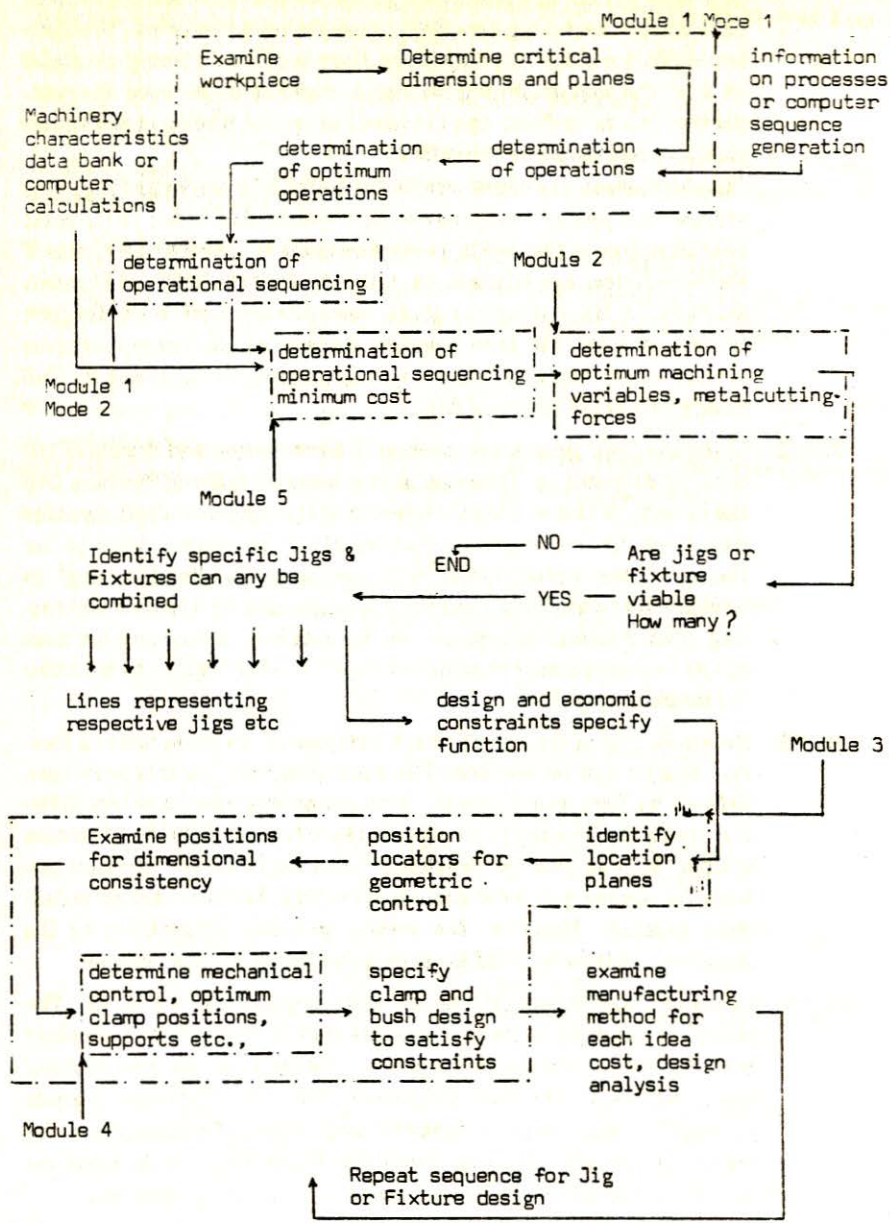
Module 1 Mode 1

Examine workpiece → Determine critical dimensions and planes

information on processes or computer sequence generation

Machinery characteristics data bank or computer calculations

determination of optimum operations ← determination of operations

determination of operational sequencing

Module 2

Module 1 Mode 2

→ determination of operational sequencing minimum cost → determination of optimum machining variables, metalcutting forces

Module 5

Identify specific Jigs & Fixtures can any be combined

END ← NO ← Are jigs or fixture viable How many ?

← YES

↓ ↓ ↓ ↓ ↓ ↓

Lines representing respective jigs etc

design and economic constraints specify function

Module 3

Examine positions for dimensional consistency ← position locators for geometric control ← identify location planes

determine mechanical control, optimum clamp positions, supports etc., → specify clamp and bush design to satisfy constraints → examine manufacturing method for each idea cost, design analysis

Module 4

Repeat sequence for Jig or Fixture design

Fig. 2 — The application areas for the modules. The modules defined in Fig. 1. are shown by the chain lines

CONCLUSION

The CAD system can be used in an interactive manner to define the locator, support and clamping system for workpiece holders required for holding workpieces during the machining operation. The system utilises a data base of machining data, that can be used for process specification, an interactive system for location positioning and support clamping positioning in conjunction with FEA. The system can become a node in a larger computerised information and manufacturing process. If a commercial system was used it would have to be interactive with high flexibility to make it suitable for the specific application of the locator system outlines GINO-F was used in this research it was suitable for the development of a system and to develop the principles. However it would not be suitable for an industrial system. Solid Modelling would be a very useful extension that would enhance the performance.

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