Integrated Computer Aided Planning and Manufacture of Advanced Technology Jet Engines

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ABSTRACT

This paper highlights an attempt at evolving a computer aided manufacturing system on a personal computer. A case study of an advanced technology jet engine component is included to illustrate various outputs from the system. The proposed system could be an alternate solution to sophisticated and expensive CAD/CAM workstations.

1. INTRODUCTION

The task of manufacturing components for advanced jet engines is indeed complex. It involves a host of procedures in manufacturing technology such as (i) Process planning and scheduling, (ii) Conceptual process layout, (iii) Process design, (iv) Design of tools and fixtures, (v)Optimization of cutting parameters, (vi) CNC part programming, and (vii) Building machining database.

A Computer Aided Manufacturing (CAM) package is evolved encompassing the above areas. The objective is to optimise the manufacturing process adopted. To achieve the objective, a modular approach is taken. The procedures are sequential but each is treated as a module. The reason is that if the information sought is available in the database of the particular module, then the procedure is skipped and the necessary data is retrieved from the module database. This approach has two advantages, that 'reinventing the wheel' is avoided and a database is built up steadily which may at some point in time override the procedures. This technique involves CAD/CAM skills, as well as database manipulation and is built employing a personal computer.

2. PROCEDURE

The flow chart of the integrated planning and manufacturing package is depicted in Fig. 1. This shows the flow of information and the route of the component. Any component loaded in the raw form for manufacturing is accompanied by the final component drawing, forging drawing as well as job card. At this stage the manufacturing schedule database is queried as to whether the component has been machined before. 'Yes' would indicate the availability of data required for machining, 'No' would imply performing the first three procedures as well as updating the associated database.
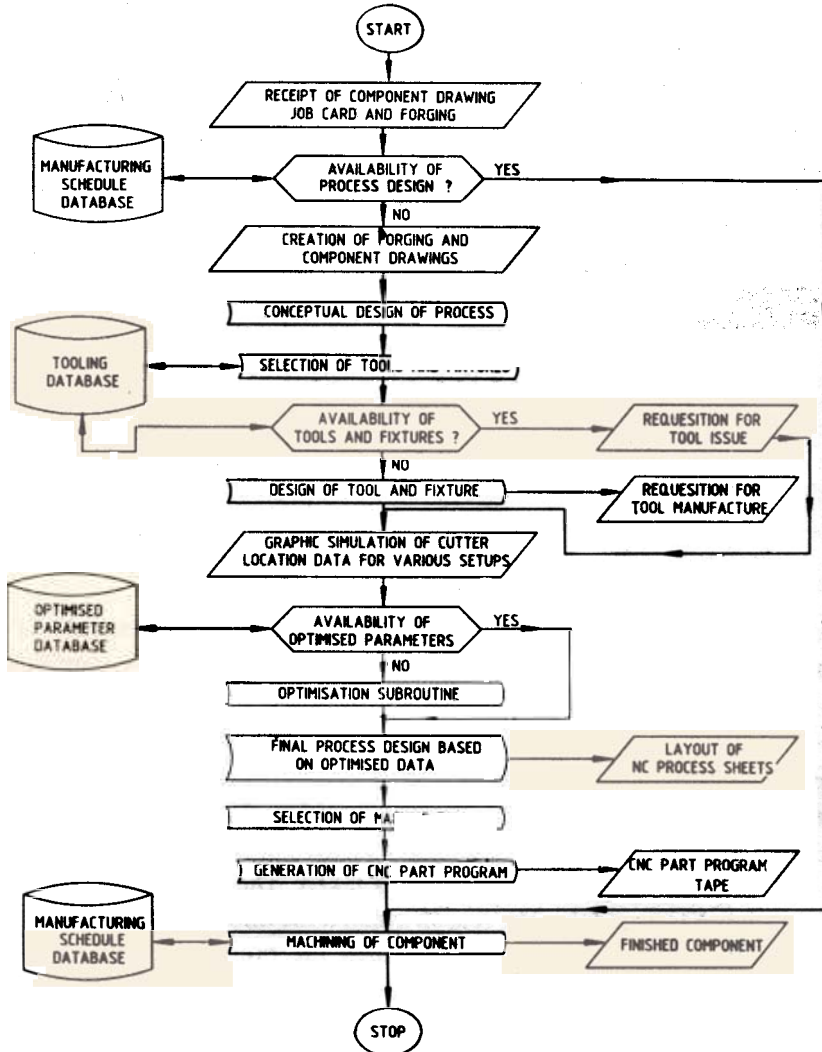

Figure 1. Flow diagram.

2.1 Process design

The inputs to the system prior to this procedure is the forging and component drawings, as two separate drawings using a computer aided drafting package. The

component drawing is superimposed on the forging drawing enabling the process designer to visualise methods of removing excess material and how to hold the workpiece. Further the types of tools and fixtures to be used becomes clear to the designer. Once the concept of how to machine the component has been roughly decided upon, the preliminary process design begins. The steps are enumerated below.

The machine tool most suited for the job is chosen and the scheduling data base is queried as to the availability of the machine tool. Non-availability implies rescheduling the job.

The type of tool to be used for different types of cuts can be ascertained at this step. Further the work holding device whether machine chuck or a special fixture becomes evident. A tool database is created. Tools are classified according to their types (for example, turning tools, grooving tools etc.) and fixtures for their purpose. Drawings are made for tools and fixtures using the drafting package and projected as a slide show when called upon. The designer views a variety of tools and when a suitable one is found the tool is moved into the cutting area for checking the possibility of tool 'fouling' the job or fixture. If the selected tooling is available a requisition note is output from the system and despatched to the tool crib operator. Non-availability of tool calls for a new design. This is done by the process designer, and drawings of the tool or fixture are taken on a hard copy and despatched along with a requisition (again output from the system) for manufacture. The tool and fixture databases are updated with the new drawings.

Once the number of set-ups, fixtures and tooling is finalised, the cutter path is graphically simulated using the drafting package and stored as a separate drawing file.

2.2 Optimization

Advanced technology jet engines commonly use Nickel based super alloys and Titanium alloys. Experiments at GTRE show these materials deviating from Taylor's modified tool life equation $TV^aF^bD^\gamma = C$. These super alloys do not demonstrate straight line graphs on a log log scale, as other materials do. A modification is brought about in the form of adding a straightening constant K to V. Three sets of experimental data is input to solve a four by four matrix in order that the values of the co-efficients a, β, γ and C are obtained. The percentage error of theoretical tool life over observed tool life is determined. The tool life equation is then substituted in the productivity equation and the optimized machining parameters are obtained. These parameters are for maximum productivity.

Prior to performing the optimization routine the corresponding databse is queried. If the optimum parameters are available, they are directly retrieved, and incorporated in the process sheet. Non-availability of the parameters imply running the routine and updating the databse with the newly obtained parameters.

2.3 CNC Part Programming

Once the above procedures have been finalised the design is frozen. This implies that no major modifications should be implemented at this stage. The process sheet

to be despatched to the CNC machine operator is output from the system. The information that is recorded on the process sheet contains cutter path, tool specification, cutting parameters, type of machine tool and details of fixtures to be used.

The last procedure in the system is the CNC part program output. The system is built to use the cutter location data of the process design to prepare the CNC part program output. A post processor is successfully designed interacting with the designer for feeds, speeds, coolant commands etc., to generate CNC part programs. The post processor produces the punched tape output of the CNC part program with necessary function codes.

Once the above procedures are accomplished the job is ready for machining. All necessary information is made available to the CNC machine operator and the machining process commences.

3. HARDWARE AND SOFTWARE CONFIGURATION

Sophisticated CAD/CAM/CAE systems are available which are dedicated for these tasks. The cost of these systems are prohibitive. The integrated system explained above operates on a low cost personal computer. The specifications of this computer system are:

*(i) Hardware :*IBM PC/XT with Dot matrix printer, A1 size plotter and high speed tape punch.

(ii) Software: MS DOS, BASIC compiler, AUTOCAD, DBMS and Wordstar.

4. CASE STUDY

The component selected for illustrating the proposed technique is the turbine disc of an advanced technology jet engine which is quite complex in configuration, the dimensional requirements are very stringent. Fig. 2 shows the forging and component superimposed. Fig. 3 shows the tool and fixture designed with this process.
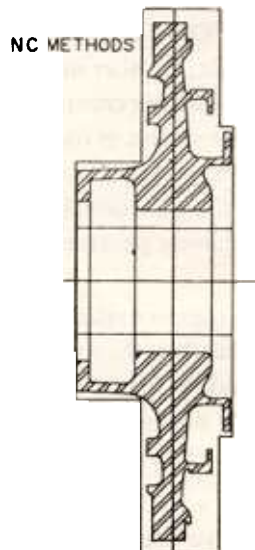

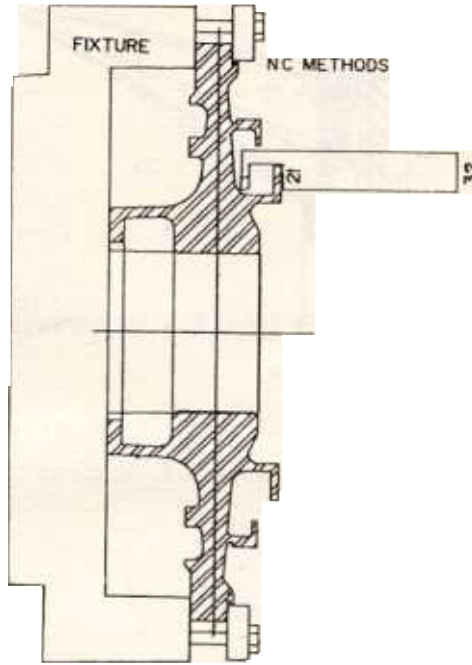**Figure 2.**   Forging and component drawing superimposed.

Figure 3. Tool and fixture design for turbine disc.

Fig. 4 shows the CNC Process sheet generated automatically by the process design software. The values of cutting speed and time are calculated using the optimization routine and written in the specified drawing line. A sample of CNC part program output is shown in Table 1.

Table 1. Sample part programme obtained by CAM techniques

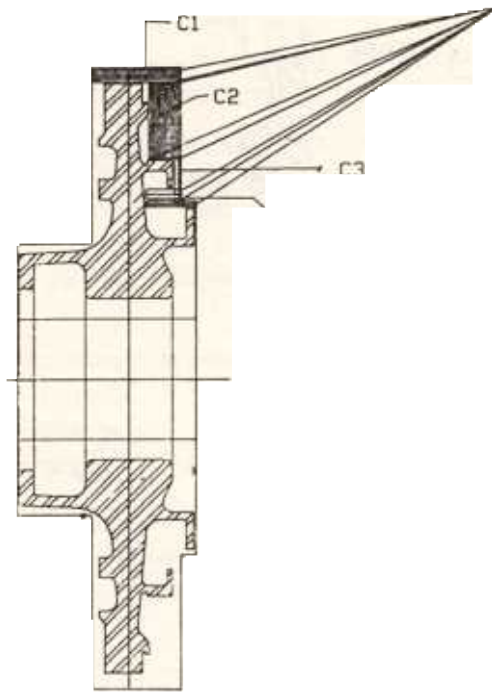|							
N 10	G 71						
N 20	G 90						
N 30	G 95						
N 40	G 00	X 600000	Z 300000				
N 50					S 07	T 010	M 03
N 60	G 92	X 100000	Z 200000				
N 70						T 0101	M 08
N 80	G 01	X 248000	Z -60000	F 1000			
N 90	G 01	X 250000	Z -60000	F 180			
N 100	G 01	X 250000	Z 84000	F 180			
N 110	G 01	X 246000	Z 84000	F 1000			
N 120	G 01	X 246000	Z -60000	F 500			
N 130	G 01	X 248000	Z -60000	F 180			
N 140	G 01	X 248000	Z 84000	F 1000			
N 150	G 01	X 244000	Z 84000	F 1000			
N 160	G 01	X 244000	Z -60000	F 180			

Figure 4. NC process sheet for turbine disc.

Cut	Tool	Length mm	Feed mm/r	Speed m/min	RPM	Depth mm	Cutting Time	Volume cu.mts
C1	PCLNL	72	0.18	80	104	2	11	8.13888E–06
C2	PCLNL	61	0.18	80	122	2	42	1.781801E–04
C3	PCLNL	35	0.18	80	159	2	10	3.36568E–05
C4	NCT1058	39	.0.18	80	175	1	8	6.00054E–06

5. CONCLUSION

The approach is to assemble various procedures in process design and planning in a single system using a modular concept. A computer based solution is adopted. An important spin-off from this system is that a database is being constantly built and updated.

The system is designed and built on·a personal computer, the cost of which is well within the reach of industries in the field of metal cutting.

ACKNOWLEDGEMENTS