INTEGRATED CAD/CAE SYSTEM FOR COLD FORGING IN THE AUTOMOTIVE INDUSTRY

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Abstract

Some progress on a European B.R.I.T.E. research project aimed at designing and developing a comprehensive and integrated CAD/CAE system for cold forging technology in the automotive industry are presented and discussed. The system is specifically designed to improve product quality and engineering efficiency in the forging departments. The system provides the designer with a suite of computer- and A.l.-based tools for both computation- and reasoning-intensive activities to be performed each time authorization is given to produce a new part by multi-stage cold forging.

1 Introduction

Due to high investments for machine tools and tooling system, cold forging is generally associated with large lot sizes and mass production. Today, in the area of production of cold forged components, that still depends to over 80% on automotive industry, there is an increasing demand for competitiveness even for small lot sizes. This competitiveness is mainly based on chances of reducing lead times and variable costs through shorter research and development times as well as shorter production runs.

Accordingly, a remarkable research effort has been recently started, promoted by automotive industry in U.S., Japan and Europe, in the direction of computer-based integration and automation of design and engineering phases in the manufacturing cycle of cold forged components.

The paper presents some progress on a B.R.I.T.E. (Basic Research Technology for Europe) research project aimed at designing and developing a comprehensive and integrated CAD/CAE system for cold forging technology (Fig. 1). The system is specifically designed to improve product quality and engineering efficiency in the designand engineering-departments. The user of the system is provided with a suite of computer- and A.I.-based tools for both computation- and reasoning-intensive activities to be performed each time authorization is given to produce a new part by multi-stage cold forging.

The system assists the designer in developing the whole process plan, including preforgings ahd tool design, process and press simulation. More reliable information may quickly be accessed, thus allowing the designer to have fast responses when alternative processes are attempted.

A particular effort was spent in developing the architecture of modules to ensure portability on different CAD- and operating-systems. It results therefore that the rnodules may be integrated with all the CAD- and operating-systems available within the industrial consortium or can be interfaced to other CAD-platforms, only a short work being necessary for each new CAD-systetn.

In the first part of the paper an outline of the system architecture is provided together with a presentation of the approach used in integrating the four different environments of which the overall system consists, namely the CAD kernel system, the CAE modules, the graphical environment and the technological database.

The latter part of the paper concentrates on the presentation of the two modules devoted, respectively, to design (generate and analyse for suitability) the forming sequences and determine appropriate machine timing and setting conditions. An application example ends the paper.

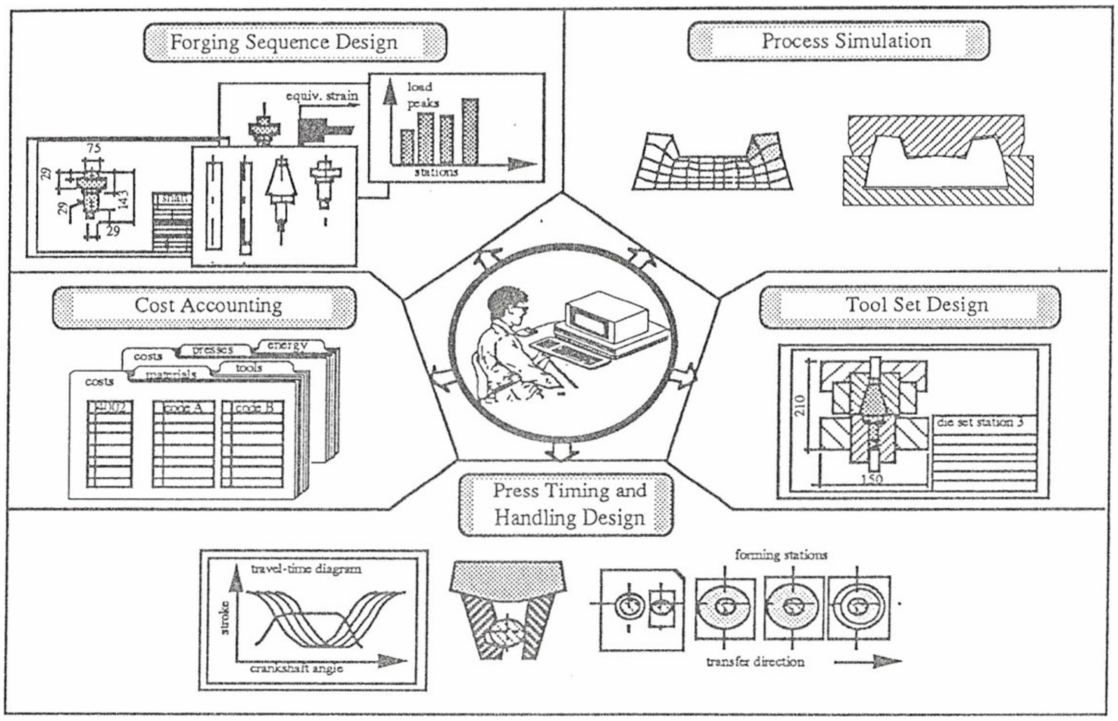


Figure 1: Integrated CAD/CAE System for Cold Forging in the Automotive Industry

2 System Architecture and Integration

The functional architecture of the CAD/CAE system has been designed in order to cover all the concurrent engineering activities leading to a complete design and planning of the process. These activities include:

(i) Designing producible preforming sequences and analysing alternatives on the basis of technological considerations,

(ii) Evaluating tool stresses and wear distribution through an accurate simulation of the metal flow into the die cavities,

(iii) Designing the set of tools,

(iv) Designing the handling devices and determining appropriate machine setting conditions, and

(v) Preparing an offer for a new product and an analytical estimating of production costs, including tooling and machine operating costs.

According to the scheme of Fig. 1, each module of the system is relative to one of the above tasks. Execution of the modules may be repeated several times, iterations being required to achieve a technical success as well as a good economic balance. System integration is directly related to the interaction between the three basic environments of which the system consists:

(i) The CAD environment, where geometric models are generated, edited and stored and graphical facilities are available as well,

(ii) The CAE environment, consisting of the application programs, and

(iii) The central DB and DBMS, for all the data making the CAE modules working and that cannot be stored in the database of the CAD system.

Since every partner of the project uses a different CAD system, a solution was to be found to develop the software for the above CAE modules in a system independent way to assure a good portability. A programming interface has been developed which allows to code the CAE applications in FORTRAN-77, independently of programming facilities offered by the CAD systems. Interaction between the CAD system and the CAE modules is at a functional level, through the call of a library of dummy routines. These routines handle each of the CAD functions required by the CAE modules. Linking the CAE modules to a new CAD system, the only requirement is the extension of the dummy routine library.
The integration between the CAE modules is through the the central database and the CAD system database for alphanumeric and graphical data respectively, the query language to the central DB from CAE modules using SQL calls.

3 The Forging Sequence Design

Designing the sequence of operations for a cold forged part is a decision-intensive activity usually performed by expert technicians. These characteristics make forging sequence design a candidate for apéfication of Expert Systems. Several systems have been designed to cope with this activity, mainly based on ES approach (references [1]-[4]). Unfortunately, only few established rules exist, so sequence design founds mainly on experience and creativeness, and each designer develops an his own style of working.
To overcome the difficulty of automatically generating sequences according to designers' style, a tool is being developed to assist the experienced designer, based on use of parametric rules and a set of interactive facilities.
According to the scheme of Fig. 2, the computer-aided design can follow different paths combining in different ways the four main activities shortly described below.

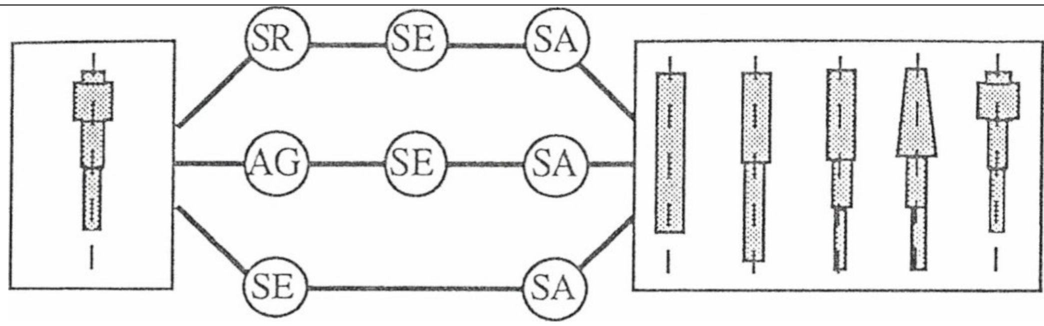
Automatic Generation

It is a rule-based system capable of generating feasable forging sequences. Problem decomposition technique and specialized data structures are extensively used to enhance its modularity and ease of maintenance. For more information see [5]. Besides the automatic generation of feasable forging sequences, the main concerns of this activity are:

(i) The ability to influence the distribution of types of operations within the forming sequence,

(ii) The ability to select alternative strategies for multiple operations of the same type, and

(iii) Editing of the technolgical limits of the different operations (e.g. limiting the upsetting ratio).



Legend:
SE= Sequence Editor
SR= Sequence Retrieval
AG= Automatic Generation
SA= Sequence Analysis

Figure 2: Possible Paths to Sequence Planning

Sequence Retrieval

According to the Group Technology (G.T.) concepts, the CAD database is accessed looking for similar parts to retrieve the forging sequence. An original G.T. code, based on geometric features and material is used to this goal.

Sequence Editor

This activity allows the interactive modification of an already available sequence. Adding and deleting forming stages, e.g. to insert precision operations, or to shorten the sequence through higher reduction values are typical features of this activity. Modifications can also deal with a single stage; in such a case the blank shapes are deformed according to the volume constancy rule.

Sequence Analysis

It is aimed at assisting the user in testing for suitability the forming sequences for forged parts. Based on an analytical approach [6], it is a tool suitable to carry out a complete producibility check and to identify the most appropriate forging sequence. The program capabilities include:

- Automatic analysis of sequences and recognition of individual operations involved at each step;
- Evaluation of the load-peak distribution and energy requirements in the differgnt forming stages. On the basis of part material and friction coefficient data as well

as blanks geometry the program calculates the maximum forming load and energy required to perform the relevant operations, and

- Prediction of the strain distribution accumulated in the blanks and the finished part.

The improvement of the engineering efficiency expected by the utilization of this module is mainly due to the fact that the designer is assisted in the complete set of activities, including intensive-reasoning as well as calculation activities.

4 The Machine Timing and Setting-up

Timing a multi-station press consists of assigning stroke lengths and positions to transfer system and ejectors at the different stations. The actions to be timed are ejection of the cut off at the feeding station, ejection of blanks at the die- and punchside and their gripping and transfer at the forming stations [7].

Timing represents one of the most critical tasks of work planning for high-productionrate machines. The whole procedure is time consuming, highly skilled and can represent a significant non-productive period for the machine. Sometimes a correct timin a can not be achieved and a partial redesign of tools or a complete revision of the whole sequence can be required.

According to actual practice, the guidelines in timing activity may be summarized as follows:

- Grasp the blank as soon as possible during the ejection and when the blank is still guided by the dies,
- Leave the blank only when the blank is surely guided by the dies,
- Avoid always collision among tools, blanks and transfer device.

The CAE module devoted to timing and setting-up of multi-station machines has been designed in order to permit

- Verifying a forging sequence for producibility on a specific multi-station press, and
- Determining a collision-free timing at every station of the press.

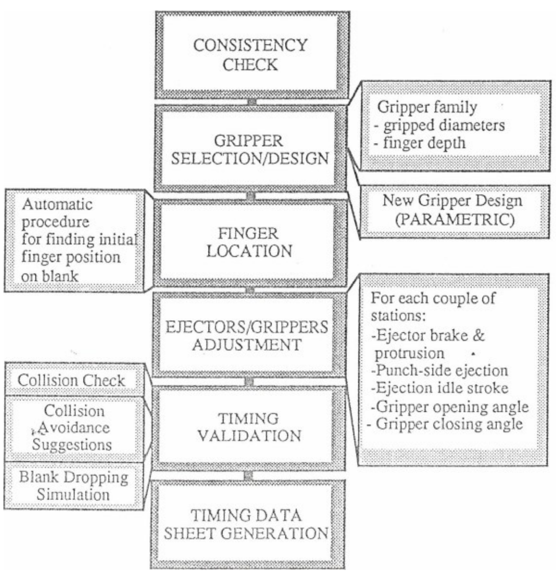
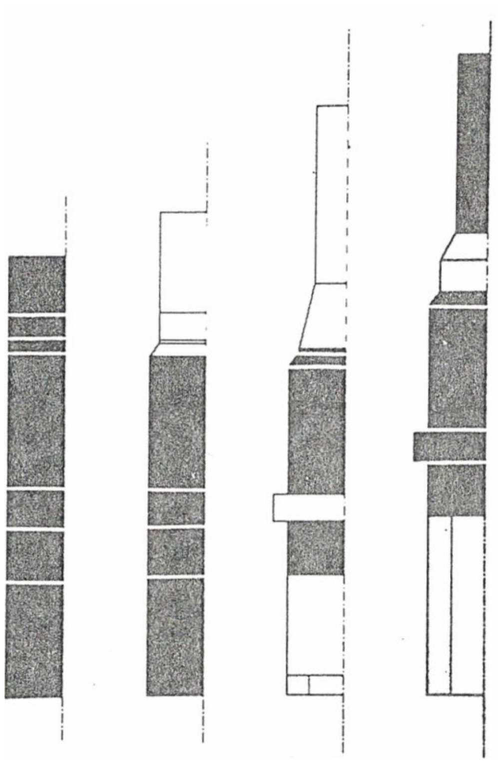


Figure 3: Functional structure of the timing module



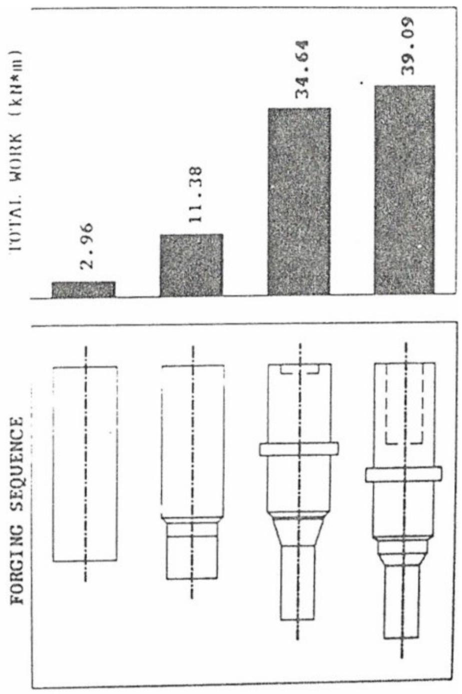


Figure 4: Three stages forging sequence *Figure 5: Evaluation of total work*

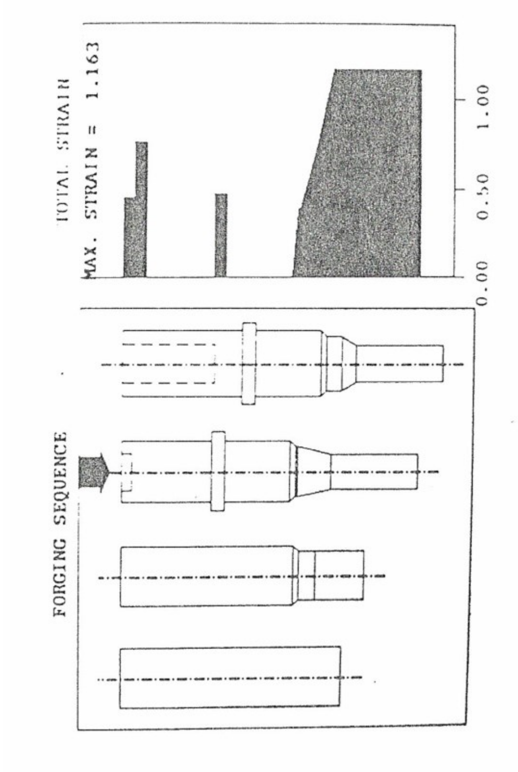
The module works as an interactive trial-and-error procedure [8] implemented into the CAD-system and using 3D-models of tools and blanks. It performs an off-line simulation of machine operation in the working area [9] and is capable of detecting automatically collisions and offering suggestions to avoid them.
The simulation is based on a kinematic model of the press which utilizes an internal representation of the travel-time diagrams of the machine that is suitable for all the classes of presses.
The module architecture has been designed to suit characteristics of both vertical and horizontal presses equipped with different gripping and transfer devices [10]. Fig. 3 shows the structure and functions of the module. These functions include

- Checking the sequence for producibility on the selected press, through a systematic comparison of press and product characteristics;
- Selecting standard grippers or designing a new set of fingers;
- Determining suitable grasping positions of the blanks;
- Deciding gripper opening and closing for each couple of stations served by the same gripper;
- Detecting possible collisions among tools, fingers and blanks;
- Suggesting measures for collision avoidance;
- Printing out the timing data sheet at the end of the timing session.

Including a general deskilling of the task, benefits expected from the utilization of the module can be summarized as follows:

- Reduction of the lead time to manufacture;
- Integration of the timing task with the other workplanning tasks;

- Less interference with production. Most of the timing of the machine is performed at the computer, while the machine can be kept in operation.



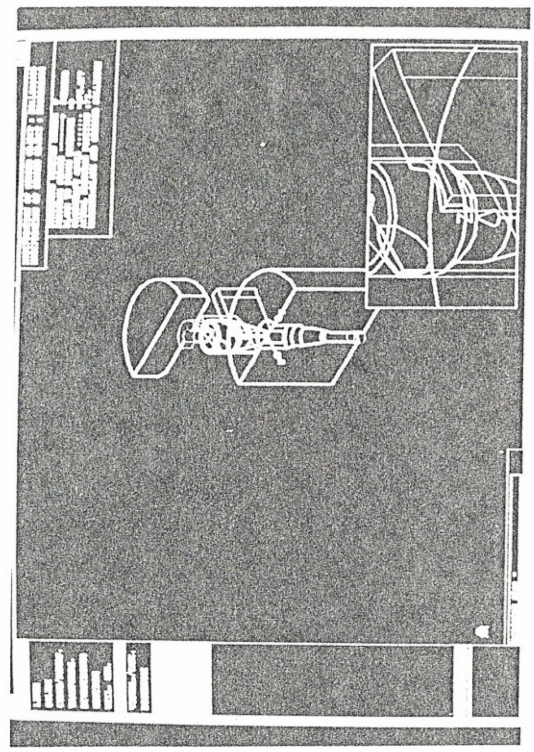


Figure 6: Strain distribution at station

Figure 7: The collision detection

5 Application Example

In order to illustrate the capabilities of the system at the present stage of development, examples are given of the output obtained from generating and testing a forging sequence of the shaft of a starting engine.

Fig, 4 shows the forging sequence as automatically generated; a different colour is used for transformed sections of blanks at each stage. The load-peaks at the shearing and forming stages are illustrated in Fig.5, while Fig. 6 shows the effective strain accumulated in the finished part.

An Hatebur Coldmatic AKP4-5 horizontal multi-station machine has been selected and timed to process the component. Fig.7 shows a step of the anirnation of the working area of the press for an intermediate stage. The prograrn has detected a collision between the blank and the fingers during the gripper opening. Two measures are suggested by the program to avoid the collision: (i) start the gripper opening earlier and (ii) changing the finger profile and grip the component further frotn the punch. At the end of the timing session a timing data sheet is produced and print out.

Concluding Remarks

Some progress on a B.R.I.T.E. research project airned at designing and developing a comprehensive and integrated CAD/CAE system for cold forging has been presented. The project is an example of effective collaboration within a group of industrial and research partners. It really tends to develop innovative tools for improvements of efficiency in design and engineering departments. The project presented in this paper is original as it encompasses all the principal aspects of process planning. It provides the designer with a suite of computer-aided tools to reduce engineering lead-time and interferences between design- and manufacturing-departments. Besides, portability of the system and use of a central Data Base make it possible the integration with several commercial packages devoted to other factory functions (e.g., production planning and stock control).

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