A CAD/CAE MODULE FOR THE TIMING AND SETTING UP OF MULTI-STAGE HOT FORMERS

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ABSTRACT

Current practice in timing and setting-up multi-station hot forging machines involves considerable time and effort from skilled personnel. This activity can be integrated into a computer assisted system for design and engineering of hot forged components, allowing the deskilling of this task and the reduction of lead time to manufacture.

The paper describes a CAD/CAE module for timing and setting-up of hot forging multi-station presses. The module is based on a 3D solid representation of the objects moving in _the working area and utilizes a kinematic model which can suite different multi-station presses.

The designer is assisted in identifying the suitable conditions for the timing of the different stages. The module includes capabilities such as automatic collision check and integrated CAD procedure for the design of grippers.

This module can be thought as a part of an integrated CAD/CAE environment for the simultaneous design and engineering of the product and process, which would assist the designer in such activities such as design of the forming sequence, design of the tooling system, writing of part programs and timing of multi stage hot formers.

1. INTRODUCTION

The correct choice of a press is a fundamental requirement for the technical and economic success in any forging production [1]. In the automotive industry, where large lot sizes and high quantity production prevail, modern mechanical multi-station machines with automatic work transfer between stations (henceforth called mechanical transfer-presses) are often preferred. High production rates, stable quality and precision of the forged product are well known advantages leading to an increasing use of this category of presses.
Timing a mechanical transfer-press requires a complete coordination of the workstation actions with the gripping and transfer system to be accomplished. Such a task needs considerable time and effort of skilled personnel and is an essential part of the work planning for the forging process which includes the design of preforgings and tools.
Recent contributions to the development of computer based systems for forging confirm the effectiveness of computerized techniques in facilitating, rationalizing and integrating the design and engineering phases in the manufacturing cycle of forgings [2-10].

In the last years a particular effort has been spent in order to produce by forging new components with complex shape such as cv-joints, gears, etc., utilizing a mix of cold-, semi hot- and hot-forming techniques. In fact the increase of interest of producers on these complex parts results from both technological and economical reasons, due to a generalized request of better properties at lower cost.
It should be considered that more complex are the products, more difficult is the design of forming sequence and tooling system, as well as the determination of a proper adjustment of the press. Therefore the manufacturing by forming of these components at increasing rate, precision and quality should be considered as an Hi-Tech task.

In order to increase the efficiency of process design and testing, the utilization of computer assisted procedures and CAD/ CAE modules offers reasonable advantages, reducing the lead time to manufacture a new product.
The designer takes advantage on defining intermediate geometries of forming sequence in CAD system, utilizing CAE procedures integrated in it, helpful in making appropriate choices (e.g. Euklid of Fides with the package ICCP for hot forging), as well as in designing the tooling system and verifying it by FEM packages (e.g. FORGE2, DEFORM, ABAQUS).
As concerns the final validation of the design and engineering task, the aspect relevant to the timing and setting-up are not specifically covered by packages allowing the off-line determination of a collision-free timing of the press.

This paper presents a computerized procedure for timing of mechanical transfer-presses which is intended as a module of a CAD/ CAE system (see Fig. 1) for the complete design and planning of the forging process. The. procedure is integrated with the CAD/CAE system and its capabilities allow the timing of different classes of horizontal and vertical presses.

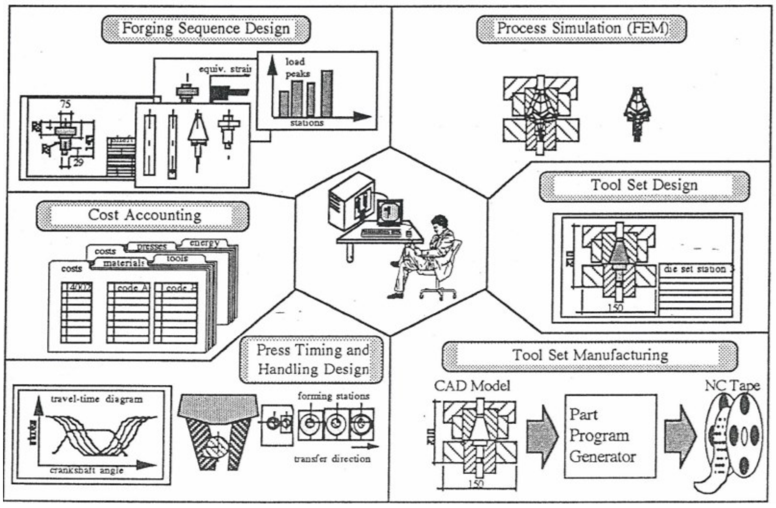

Fig. 1. The Architecture of the Integrated CAD/ CAE System for Forging Technology.

2. MECHANICAL TRANSFER-PRESSES AND THE TIMING PROBLEM

On the basis of their architecture, mechanical transfer-presses [12] can be distinguished into (i) horizontal and (ii) vertical presses. They can be equipped with different types of devices [13-14] for handling the partially completed parts among the different stations. The most usual transfer and gripping devices are illustrated in Fig. 2.

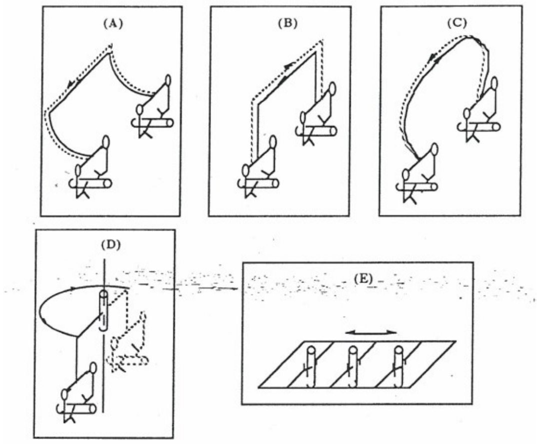

Fig. 2. Typical transfer devices in mechanical transfer-presses.

The transfer system is always synchronous, with a gripper unit for each pair of adjacent workstations, the actions of the gripper fingers and the transfer motion being simultaneous. Horizontal presses can be equipped with the transfer mechanisms A, B, C and D of Fig. 2, whereas vertical presses utilize the device E or a devoted external manipulator.

The transfer mechanism must not only move the blanks from the station from which they have been ejected to the subsequent one, but must also locate and hold the blanks in the correct position until the punches impact and push them into the die-cavities. Accordingly, gripping and transfer of the blanks require to be coordinated, with split-second timing and accuracy, with workstation actions such as ejection of the cut-off at the push-out station and die-side and punch-side ejection of blanks. Positions and stroke lengths are assigned to the transfer and gripping system as well as the ejection devices. This must be done in such a way to avoid typical problems, such as improperly gripped blanks, dropping or canting of the blanks when pushed into the dies and fingers colliding against the blanks or the punches. Stroke length and position for each device are controlled by individually adjustable cams.

The timing procedure is, therefore, part of planning the forging process, contributing to the check of the forging sequence design for producibility on the candidate machine. Sometimes a correct timing can not be achieved and partial redesign of tools or complete revision of the preform sequence can be required.

In current practice, most of the activities involved in machine timing are performed together with the machine setting up at the site of the machine. Thus, the non-operational contribution to the manufacturing lead-time is increased and the producibility check postponed to production trials in the shop-floor.

An appropriate timing is accomplished at the end of a trial-and-error procedure using the real machine and related documents, such as the travel/time diagram (a simplified example is given in Fig. 4), the tool-set assembly and the finger-path diagram.

3. THE CAE MODULE FOR TIMING

The CAE module for timing has been developed [151 in order to permit:

- verifying a forging sequence for producibility on a specific transfer press,
- determining a collision-free timing at every station of the press,
- integrating the timing task with the other concurrent engineering activities in planning the forging process.

The major benefit expected through the use of this module is that a large part of the work concerning the setting up of the machine is removed from the shop floor, as the setter is presented with acceptable timing data for the machine. In details advantages relevant to the use of a computerized procedure can be summarized as follows:

- less interference with production and reduced-set up times. The most labour-intensive tasks are performed away from the machine which can be kept in operation producing other parts and they are transferred to the domain of the planner. Timing sheets are prepared by the planner more quickly, allowing the set-up to be performed more efficiently;
- incorporation of the collision check. The module detects automatically any collision among blanks, tools and grippers and offers suggestions to avoid them.

3.1 The Module Architecture

The module works as an interactive "trial and error" procedure implemented in a commercial CAD-system (Euclid-IS of Matra Datavision). The functional architecture of the module (see the scheme of Fig. 3) has been designed in such a way to cover all the activities leading to a complete and correct timing workplan of the machine. These activities 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 pair of stations served by the same gripper;
- detecting possible collisions among tools, fingers and blanks and suggesting measures for collision avoidance;
- printing out the timing data sheet at the end of the timing session.

After the consistency check between process requirements and machine features has been accomplished, all the following activities until the timing validation are performed in turn for each pair of adjacent stations served by the same gripping and transferring unit, starting from the feeding station up to that where the finished blank is discharged. For each pair of stations, the use of ejection brake and the value of the ejection protrusion are decided. The following basic operations are then timed:

- gripper opening at the 2-nd station,
- punch-side ejection at the 2-nd station,
- die-side ejection at the 2-nd station,
- gripper closing at the 1-st station,

this sequence permitting the timing to be achieved in a minimum number of try-outs.

3.2 The Machine Model

The simulation of motions utilizes 3-D models (C.S.G., boundary- or surface-models) of the objects moving in the working area and is based on a kinematic model of the machine which permits to evaluate at each step of the simulation the positions of the objects.
This model is derived from the travel-time diagrams of the machine, which are usually furnished together with the machine and currently used by sequence designer and machine operator to perform the timing. These diagrams (an example is in Fig. 4) give for each tool (punches, ejectors, grippers, transfer device and pressram) a family of curves. Each family describes the position of the corresponding tool as a function of both the crankshaft angle and an adjusting parameter (e.g. the ejection stroke for the die-side ejector).
A general representation of these diagrams, suitable to every class of presses, is based on a piecewise polynomial approximation, which uses cubic segments and ensures the first derivative continuity.

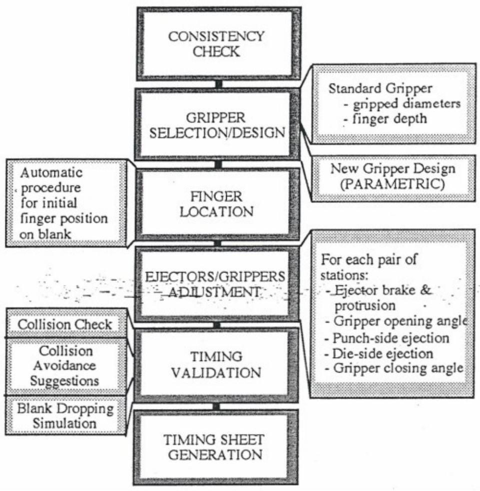

Fig. 3 Structure of the Timing Module.

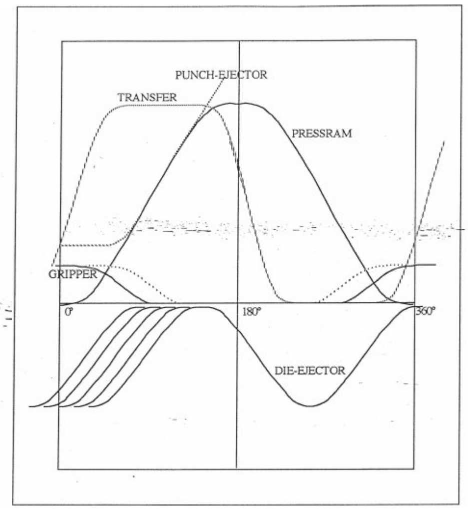

Fig. 4. The travel-time diagrams of an Hatebur AMP70 press.

4. EXAMPLE OF A WORKING SESSION

Some screens and printouts are given relevant to a working session relevant to the timing of a forging sequence of a CV-joint on an Hatebur AMP70 press. Fig. 5 refers to the timing stage where the user decides the pressram position at which the gripper starts to open. Fig. 6 shows a collision detected between the gripper and the blank during the gripper opening at the 4th station.

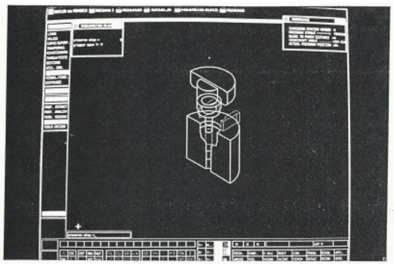

Fig. 5. The gripper opening stage.

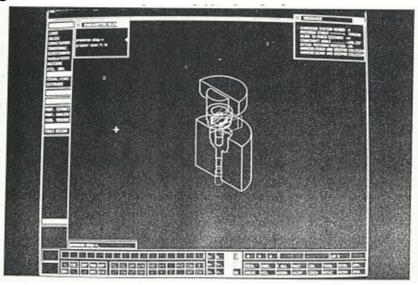

Fig. 6. The collision detection.

Two alternative measures suggested to avoid this collision phenomena are (i) changing the gripper geometry and (ii) anticipating the gripper opening. According to the two measures, the user goes back in the timing and modifies the gripper shape or the pressram angle at which gripper opening starts. The timing-data sheet relevant to the correct timing is printed out at the end of the working session.

5. CONCLUDING REMARKS

The new elements of a computerized procedure for timing of mechanical multi-station machines with automatic transfer between stations have been presented. The procedure assists the user in identifying suitable timing conditions for the different stages of the timing and setting-up tasks, including collision check and design of non-standard grippers. In addition to advantages such as increased efficiency and reduced time in preparing timing sheets, the use of the procedure has the important implication that a large part of the work concerning the producibility check of the product and the machine preparation are removed from the shop floor and integrated with the process design activities.

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