A combined automatic and parametric approach in designing the tooling system in forging.

Berti G., D'Angelo L., Yang J.J. and Bariani P.F.
DIMEG - Dipartimento di Innovazione Meccanica e Gestionale
Università di Padova, via Venezia,1; Padova 35131

Summary

The paper illustrates the approach underlying a CAE module for the design of the tooling systems in forging technology that has been developed and implemented by the authors into a high-level parametric CAD system and, then, validated in the tool-design department of a forging company.
The approach is based on the classification of possible configurations of punch- and die-side tool assemblies and combines the automatic retrieval of the tool assembly configuration for a specific stage of the press with the automatic scaling and fitting of individual tool components and assemblies thanks to the parametric modelling and pre-defined assembly rules.

Key words: Forging, die design, CAD/CAE

1. Introduction

In designing forging processes, an efficient utilisation of computer is becoming very promising because of the possibility to integrate in an environment various activities, such as designing the forging sequence and the tool-system, setting-up the press and estimating the different cost items [1, 3, 9, 10].

This paper presents a CAE module which assists the planner in designing the tooling system to produce forgings on multi-stage transfer presses. The module has been developed and implemented by the authors into a high-level parametric CAD system and is to become a part of an integrated CAD/CAE system for the design of the overall forging process [3].

The approach underlying the module is based on the classification of possible configurations of punch- and die-side tool assemblies and combines the automatic retrieval of the tool assembly configuration for a specific stage of the press with the automatic scaling and fitting of individual tool components and assemblies thanks to the parametric modelling and pre-defined assembly rules.

The three main functionalities of the module are represented in Fig.1. They include:

i) classification and coding of die- and punch-sets based on attributes such as shape of the blank, forming operations and specific press,
ii) generation of the serial CAD macro-commands for automatic retrieval and assembly of the tooling structure,
iii) customisation of the tooling set and designing of the product-specific tool-components.

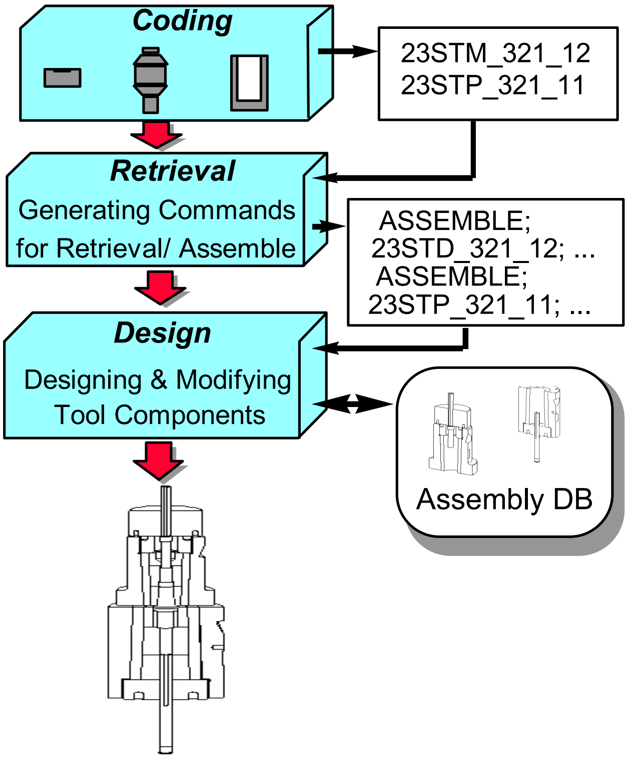


Fig. 1 Architecture of the hybrid environment.

2. Current Practice in Tool Design

The approach underlying the computer-assisted procedure presented in this paper is based on the results of the analysis carried by the authors on the current practice in process planning at the tool-design and tool-making departments of a forging organisation that produces high-volumes of forged parts, mostly for the automotive industry. Design and manufacture data concerning the tooling systems of more than 60 forged parts processed on 8 different multistage transfer machines have been analysed.

A significant finding of the analysis is that the tool design procedures that are conventionally taken in the company may be classified as follows:

1) when a new product can be considered enough similar to an already produced one, the same press and tool assemblies are employed and only the components that contact the blanks, such as punches, dies and ejectors, are modified or re-designed. This is possible due to the well defined spectrum of forging categories produced by the company and the large number of manufactured tool systems.
2) sometimes the new product is different from those experienced, but its forging sequence consists of blanks similar to others in the database; in this case new combinations of available punch- and die-assemblies can be used to develop new tool-sets.

3) if a new product is completely different from the past examples, the new assembly of tool structure has to be designed and examined. After that, it can be added in the database for further use.

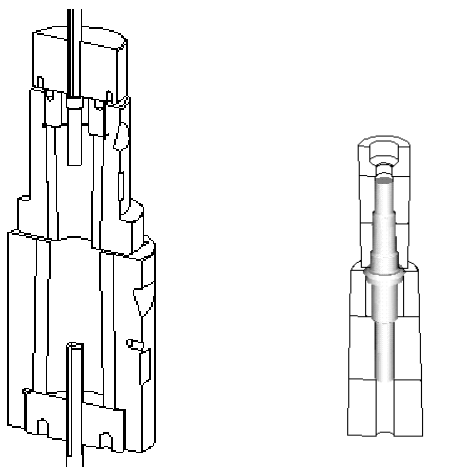
Accordingly, the whole design activity can be said as a retrieval type design, with the advantage of utilising standard tool structures so that tool system cost can be reduced. As a consequence, the majority of components for a new tool set are already available and only those which contact the blank need to be redesigned. For the same reason, each press is used to produce specific families of workpieces.

3. Tool System for Multistage Presses

Forging parts can be processed on a variety of different machines [7]. Each stage on a particular press has, in the punch- and die-side block, standard recesses of a fixed volume for the tooling and this space is filled with very similar distributions of tool element's weight, independently of the operation performed [2];

The tool-system at each press stage can be considered as consisting of two main parts (Fig. 2):

- an outer part (hereafter called *tool-holder*), which is made up of the *basic tooling system components,* that are used in every configuration of the tooling (e.g. housings and pressure pads) and *the tool configuration components*, that are additional general components bringing the tooling system to a specific configuration, e.g. fixing dimensions of the punch head and ejectors,
- an inner part (hereafter called *tool-core*), which consists of most of the product-specific tool components.



(a) (b)

Fig. 2 Tool-holder (a) and tool-core (b) in a tooling system for a multi-stage press

The assembly configurations of the tool-holder are directly correlated with the category of the press and forming operation at that station, whilst the configurations of the tool-cores depend on the profile of the forged blank, in addition to the product category.

The tool-holders are classified into families of punch- and die-side assemblies, each of them grouping tool-sets that share the same combination of the following attributes:

- the shape of the blank,
- the forming operations, and
- the press, where the tool-set is fit.

4. The Approach to the Tool System Design

Designing the forging tool system is a decision-intensive activity performed by expert technicians.

To overcome the difficulty to automatically generate the tooling assemblies according to the designers' style, a hybrid environment has been developed to assist the designers, including three functional modules: (i) the *coding module*, consisting of a set of interactive facilities for coding the current forming stage, (ii) the *retrieval module*, for automatic retrieval and assembly of the tooling system, and (iii) the *design module*, where rules for parametric designing and interchanging new tool components are defined. This environment has been developed and implemented into the CAD system Pro/Engineer™ of Parametric Technology Inc. The architecture of the environment is shown in Fig. 1. It presents these three main steps to design a complete tool-set at a generic station of a multistage press.

4.1 *The Coding System*

This module is used to assign a code to each blank of a forging sequence [4]. The blank code is the key to access the database and retrieve the suitable punch and die tool-holders, when available.

All attributes significant for the design task are collected by means of a set of menus developed externally to the CAD system and including selection of (i) the press, (ii) the functional family of the component, (iii) the class of the blank shape (according Wagener's rules) and (iv) the forming operations at the punch- and at the die-side. From this information the blank code is automatically derived.

The classification plan for the blank shape is partly derived from Wagener [11] and can be extended to non axisymmetrical shapes.

An example of a blank code is given below:

32 ST_322_D12_P11

press code → 3
forged component code → 2
code of blank shape → ST
code of die-side operation → 322 / D12
code of punch-side operation → P11

For each forming stage, only the features of the blanks which are deformed are taken into account (the dark surfaces in Fig. 3). Punch-side forming operations are considered distinct from

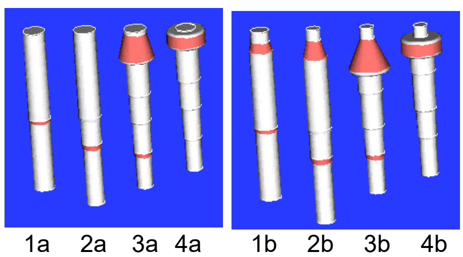


Fig. 3 The sequences for two jackshafts

die-side ones. Fig. 4 shows the classes for blanks in Fig. 3.

Punch- and die-side assemblies of the tool-holder are represented by two individual codes derived from the blank code, as shown below:

32STD_322_12 ---- code for die-side;
32STP_322_11 ---- code for punch-side.

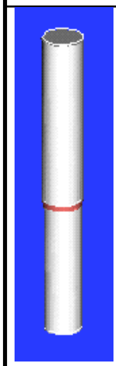
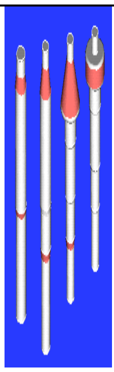
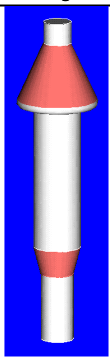
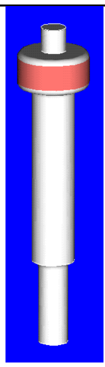
1a, 2a	1b, 2b	3a, 3b	4a, 4b
-	reducing	conical head ing	heading
			
reducing	reducing	reducing	-

Fig. 4 Blank classes for the sequences of Fig. 3

The tool assembly database is accessed using these codes as searching key: the tool sets which match the query can be retrieved. Two situations are possible :

(i) a tool-set exists for the forming stage, which can be immediately retrieved and used,

(ii) if it is not found a suitable assembly, the software shows the user all those available for that press. The designer is in charge to decide if few adaptations (case (a)) are enough to create the new assembly from one available, or if a new assembly must be designed from scratch (case (b)). In the former case the designer chooses the most suitable assembly. In both cases (a and b) a new code is automatically assigned to the new assembly.

4.2 *The tooling system retrieval*

This module is utilised in the cases (i) and (iia) presented in § 4.1.

It is integrated as a function of the parametric CAD system to retrieve files of the blank, the punch- and die-side tool-holders. Macro commands are generated to match the tool-holder codes with those available in the CAD database and to retrieve files. After that, a new tool-set assembly is automatically created for the current forming stage by assembling all parts.

The several assemblies pertaining to the same family of tool-holders are represented as variations of a single standard assembly consisting of parametric tool components referencing each other for positions and dimensions.

4.3 *The tooling system design*

The third module is useful to edit the retrieved assemblies and to design the new ones and has been developed directly inside the CAD system. A set of menus have been created for assisting the user in the design tasks. The main steps when using the module are, as follows:

- editing (cases (i) and (iia)) or design (case (iib)) of punch- and die-holders,
- positioning of blank with reference to the tool parting line, and
- design of tool-cores components.

Tool-core assembly components are represented in libraries of individual tools classified according to their functionality (e.g. heading dies, reducing dies, etc.), and their location in tool-set assembly. Alike the tool-holders, the components of the tool-core assemblies are parametrically designed around the blank and inside the tool-holder, referencing them as concerns dimensions, positions and the geometry profiles.

5. Illustrative Example

The blank shown in Fig. 5 is used as an example to illustrate the working of the module. It represents the fourth forming stage in the sequence of a primary shaft of a FIAT car gear-box produced on an automatic 5-stage horizontal press.

The code of the blank is based on the following attributes :

- press: National 1875;
- standard primary shaft;
- shape class of the blank with code 322;
- forming operations: reducing (p31) at the punch-side and heading (d21) at the die-side.

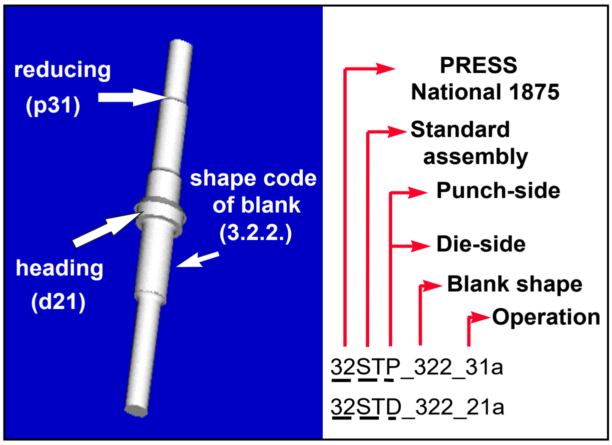


Fig. 5 Code of the examined blank

The two codes generated by the module and represented in Fig.6 are used for accessing the database of the CAD system. Since similar components have already been produced and in the CAD database suitable tool-holders are available for both punch- and die-side (case (iia) of § 4.2), the relevant assemblies of Fig.6 are retrieved.

The two tool-sets are then automatically assembled (Fig.6) taking in account the codes of the punch- and die-side tool holders.
After positioning the blank with reference to the tool parting line, the user is assisted in adjusting the dimensions of the tool-holder components (specifically, the punch head and the ejector (Fig. 7a). The tool-core parts are then designed interactively using two different approaches : i) for axis-symmetric shapes the designer utilises the blank profile, ii) for non axis-symmetric shapes uses the blank model as a tool to cut the solid core component. A complete tool-set assembly is shown in Fig. 7b.

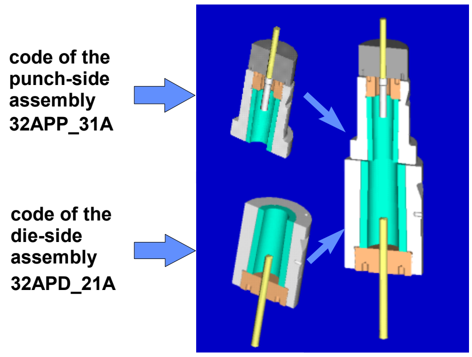
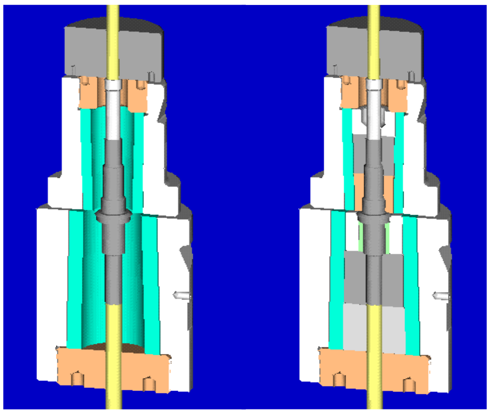


Fig. 6 The retrieved tool-holders

Relations are automatically established between the dimensions of the blank and of tool-core components. When the forging tools must be designed for a new blank very similar to that just processed (case (i)), the dimensions of the tool-core components are automatically adjusted.


(a) (b)
Fig. 7 (a) Configuration after blank positioning and
(b) after design of tool-cores

6. Conclusions

A CAE module for the design of the tooling systems in forging technology has been developed and implemented by the authors into a high-level parametric CAD system. The module is to become a part of an integrated CAD/CAE system for the design of the overall forging process.

The variant approach underlying the module is based on the classification of possible configurations of punch- and die-side tool assemblies. The automatic retrieval of the tool assembly configuration for a specific stage of the press is combined with the automatic scaling and fitting of individual tool components and assemblies thanks to the parametric modelling and pre-defined assembly rules.

At the time of writing, the module has been validated in the tool-design department of a forging company (where it is currently in use) for a significant number of classes of forgings, including parts with deviations from rotational symmetry.

Acknowledgements

The work on which this paper is based is part of a joint research activity carried out at DIMEG - Dept. of Innovazione Meccanica e Gestionale of the University of Padua and TEKSID S.p.A. - Divisione Componenti Acciaio, in the frame of the research project EUREKA-FAMOS EU-668 “E.F.FOR.T” sponsored by the European Union and M.U.R.S.T. - the Italian Ministry of University and Scientific and Technological Research.
Messr. M. Marengo, M. Vianello and A. Clausi of TEKSID S.p.A. are gratefully acknowledged for their collaboration.

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