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DEVELOPMENT OF THE EXPERIMENTAL INTEGRATED DESIGN ENVIRONMENT FOR PROGRESSIVE CUTTING DIES

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Abstract: *In according to the increasing amount of contracts in Estonian sheet metal industry, more attention is addressed to manufacturing the different types of dies. In this paper elaborative tasks of integrated design environment for progressive cutting dies are observed.*
To have a maximum impact of the optimization and the same time to reduce the volume of design work, attention is focused on the phase of conceptual design and on the different selection techniques of the "most feasible" components (embodiment design).
The objective of this work is to develop different techniques of creating parametric feature-based 3D model libraries and to evaluate their rationality, using midrange CAD package "Solid Edge".
Key words:
CAD, Design environment, Progressive die design, Solid Edge

1. INTRODUCTION

Producing sheet metal parts with progressive dies for mass production have been widely demanded in various industries such as electronics and machine tools. In according to the rising amount of contracts in Estonian forming and cutting sheet metal industry, more attention is focused to development stage of different types of dies.
Since the progressive dies are widely used and generally customer-oriented, the faster changes in composition of different modification become an important issue.
The progressive dies are generally very complex. They could perform piercing, notching, cut-off, blanking, bending, shaving, drawing, trimming and other miscellaneous forming operations at a single setup.
The development of the new products and manufacturing processes in the modern manufacturing system are cross-functional and teamwork-oriented activity, which integrates engineers from different fields of competence, suppliers, partners, and customers so that they can share knowledge, synchronize schedules, manage deliverables and specify requirements (Küttner, 2002).
To support these activities for die designers a new production development paradigm (called development environment - DE) is needed.
Historically, these activities are carried out manually, based on designers' trials-and-error experiences, skills and knowledge.
Recent advances in the field of artificial intelligence (AI) have given rise to the possibility of constructing knowledge-based systems that incorporate built-in intelligence and apply diverse knowledge to solving the different kind of design problems. It is self-evident that designers could use these kinds of the knowledge-based systems to solve design problems in development stage of a new progressive die also. For example they could use these knowledge-based systems prosperously for scrap strip layout, die block, punch plate and stripper layout design automation etc.
The solutions of some knowledge-based progressive die design work related to our study can be found in various wizards which pertain to different high-end level CAD packages like Pro/Engineer and Unigraphics.
Unfortunately majority of Estonian SME's cannot afford the price per seat of these kinds of high-end level CAD packages. Therefore mid-range level CAD packages (particularly Solid Edge) are widely used.
The objective of the work is to propose guidelines and possibilities for a design environment of progressive cutting dies using mid-range level CAD package „Solid Edge". Make design efficient and cost-effective, reduce the cost of standard and prefabricated components and decrease the time needed for overall blueprint of progressive die.
Development of the environment is focused on the use of standard components, reuse of successful past die designs, methods and etc.

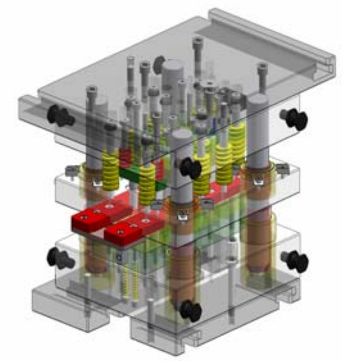

Figure 1. Progressive die 3D model representation modelled in Solid Edge.

2. DEFINITION OF DESIGN ENVIRONMENT

The Design Environment (DE) is an objective-oriented network of Engineering subsystems / teams and activities through which the new product and production are developed and managed, which includes (Küttner & Eljas, 2001):

- Product development
- Manufacturing process planning
- Manufacturing planning and control, resource and inventory management
- Strategic product portfolio management
- Sales and marketing
- Purchasing of components and materials.

The different design tools and systems that support the design process, to utilization of design knowledge, and to integrate traditional CAD and knowledge engineering are consisted in the integrated computer-aided DE (Dieter, 2000).
In this paper we put the structure of an integrated design environment forward.

Development of the techniques of concurrent engineering for management groups of designers who participating concurrently in design of different (but conceptually similar) progressive cutting dies should provide design support and coordination aids to the designers.

Each client using the DE can run its own CAx application modules and participate in some mode of collaborative design. Previously specified abstractions of the product families and data models of products, their components, materials and so on should be consist in DE.

Traditional product development process could be represented as process with serial steps (subsystems) coordinated by a single chief engineer or core team. Design methods based on the model of a central or chief engineer have been widely used in product and production development and have proven to be effective for restricted and simple cases, when a single chief engineer or core team is able to develop and apply design tools, share the design tasks and information for whole variety of different die products.

As problem becomes more complex it is more difficult for a central group to manage the process. The system must become more decentralized, communication requirements become more severed. Difficulties in communication and organization of design process could arise and should be minimized.

Generally the efficiency of DE is affected by the selection of a suitable and effective system decomposition method that identifies fully and clearly all the sub-systems and supports efficiently the interactions between them. Considering product and manufacturing process development tasks for a single die component or a family of similar die products the typical (simplified) architecture of DE together with the connections among different tasks (teams) in DE is illustrated in figure 2.

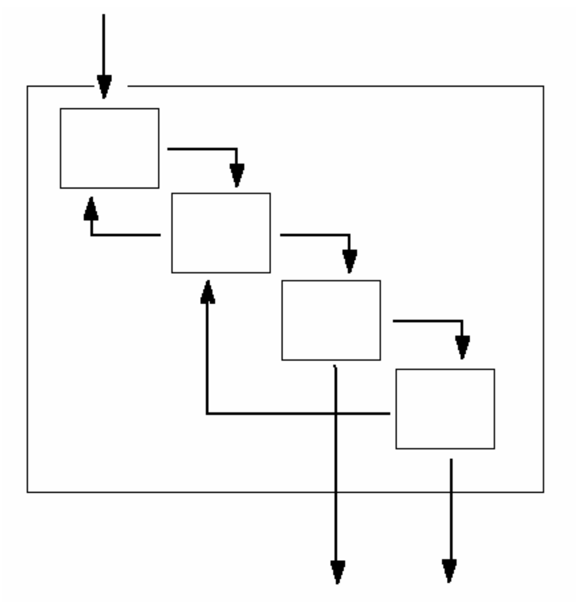

Figure 2. The simplified scheme of DE

Here, it is assumed that the development tasks are executed serially, from upper left to the lower right side. The lines connecting one task to another on the upper right side represent feed-forward, while the lines to the left or below represent an iterative feed-back. The system has feedback, which mean that some needed information is generated by the tasks occur later in the process, i.e. the upstream tasks need information from the downstream tasks. If the sequence of tasks is kept this way, earlier tasks have to proceed with the incomplete or incorrect information, and this will lead to necessary iterations and rework of some tasks.

To minimise the amount of feedback and the related rework, the system should be re-arranged in such a way, that the required information is generated before it is needed, with the objective to minimise the extent of feedback connections and minimise the number of iteration (fig.3).

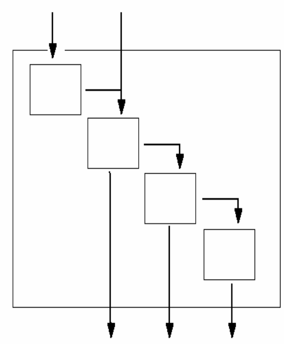

Figure 3. The system with feed-forward structure

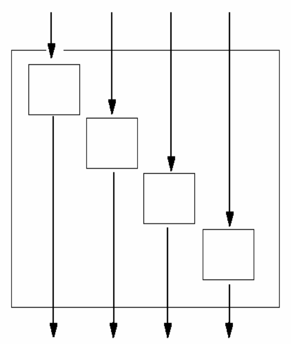

Figure.4 The system with parallel structure

When one applies the same concept to the feed-forward connections as well, the structure represented in figure 4 is produced. This simple system represents decomposition of the original problem not only free of iteration, but also parallel. In this case the requirement enforces that the results of the one task match to the input of another one, permitting serial tasks to be parallelised in transparent manner. As the development (design of die components and processes) proceeds, the discrepancy between the assumed inputs and those proposed by the supervisory subsystem design variables values is considered to reduce continuously with the objective to reach a specified feasibility tolerance level (consistent level of accuracy).

There are several reasons for composition of the global task:

- The division into smaller functional details lead us to better understanding of the whole design task.
- Breaking down the functional subsystems may lead to the realisation that there are some already existing components that can provide some of the functionality required.
- The resulting decomposition controls the search for solution the initial problem.

In order to co-ordinate DE effectively, the similarity between the new task and solutions which are stored in design database need to be identified. The computer supported tools for the design of the feature extraction and retrieval of similar solutions must be developed. Including the analysis of previous experiences of the progressive die design and the development of recommendations based on the prognoses and recommendations (templates) of the best practices. Evaluation must be incisively and knowledgeably done, and all the issues must be considered as thoroughly as possible. Through the evaluation designer develops a great deal of useful information about the die design.

3. **CONCEPTUAL DESIGN OF PROGRESSIVE CUTTING DIES.**

The development of progressive die is separated to multiple design tasks. Elaborating these tasks one by one is time consuming proposition.

Commonly stamping process planning starts with an investigating part drawing of stamped metal part to work out a material strip, followed by nesting the pattern to produce a blank layout.

Next, stamping operations are planned and operations are assigned to die stations. The resulting plan is typically represented as a strip layout (the productivity, accuracy, cost and quality of a progressive die mainly depends on the strip layout), which guides the subsequent die structure design like selection of the die block, the blanking punch, piercing punch, punch plate etc.) The final step is to prepare the Bill of Material.

The guided design process required for designing a stamping die consists of fourteen steps (Paquin & Croweley, 1987).

All these requirements for the progressive die design steps are well presented in wizard of high-level CAD package „Unigraphics“ called „Progressive Die Wizard“ (fig 5) (Progressive Die Wizard Help, 2003).

Typically the functional requirements of design are examined for functional, technical, operational, and economical feasibility aspects.

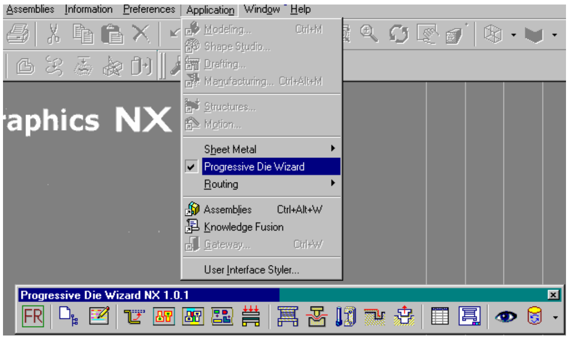

Figure 5. „Unigraphics's“ „Progressive Die Wizard“

Although the mid-range CAD package „Solid Edge“ doesn't contain wizard which should lead the die designer through the design process we could however try to use similar techniques to elaborate out a conceptual progressive die design steps.

Certainly we should lead to our attention of following aspects:

- Ergonomics, and safety standards
- Economical and organizational requirements (cost. lead time, maintenance, production schedules, etc)
- Dimensional requirements

The conceptual design is a phase where the designer can design without focus on details and yet is able to introduce enough information to evolve a full design from this work.

4. **EMBODIMENT DESIGN OF THE PROGRESSIVE CUTTING DIES**

General objective of the embodiment design phase of a die design is to make design cost-effective and efficient. It means to increase manufacturing productivity, reduce the overall cost of design work and the cost of standard and prefabricated modules, and to limit the time needed for progressive die implementation.

After defining a progressive die design process, we should going through a pre-defined series of steps. Generalised structure of the design as a structured series of dialogs should be proposed in the phase of embodiment design (fig. 6).

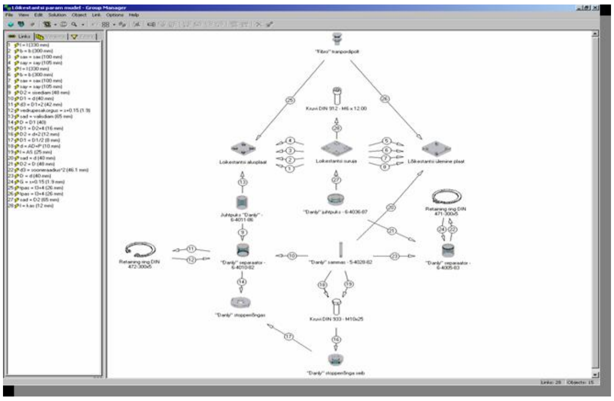

Figure 6. Generalised structure for progressive cutting die

The following are the important features of the proposed representation of a generalized structure of the progressive die design:

- It represents generic structure, called generalized logical structure of a so called family of progressive dies.
- It represents the relationships between parent-item variants as constraints (i.e. parameter and parameter value constraints, the interfaces or connections between components, inter-component compatibility constraints and goes-into relationship constraints) which limit component variants to only those that are both technically and economically feasible.
- Users can re-run the die design process and modify their previous work. They can get back to revise what they have created (even if it is a minor change).
- Users need to understand the implications of each choice they make in the DE system, they need to know that their choices will produce the results they expect.

Component selection is typically part of making a decision in terms of multiple constraints and multiple criteria or objective functions. Components selection involves the following important issues: (Küttner & Nekrassov, 2002)

- Availability
  - Are there multiple sources of supply?
  - What is the likelihood of the components availability in the future?
  - Does the component correspond to the requirement is needed?
- Quantity limitations of order
- Variability in functional parameters, dimensions and other parameters
- Costs.

The term component is used in the generic sense to include special purpose parts, standard parts, assemblies (standard or special purpose) or modules.

CAD knowledge and databases (fig 7.) are vital to designers in the phase of the embodiment design, who search through

vast amount of corporate legacy data and navigate on-line catalogues to retrieve the right components for assembly into new products.
The system includes the database of 3D models of progressive die components, which can be selected in the dialog with the designer to generate a progressive die model.

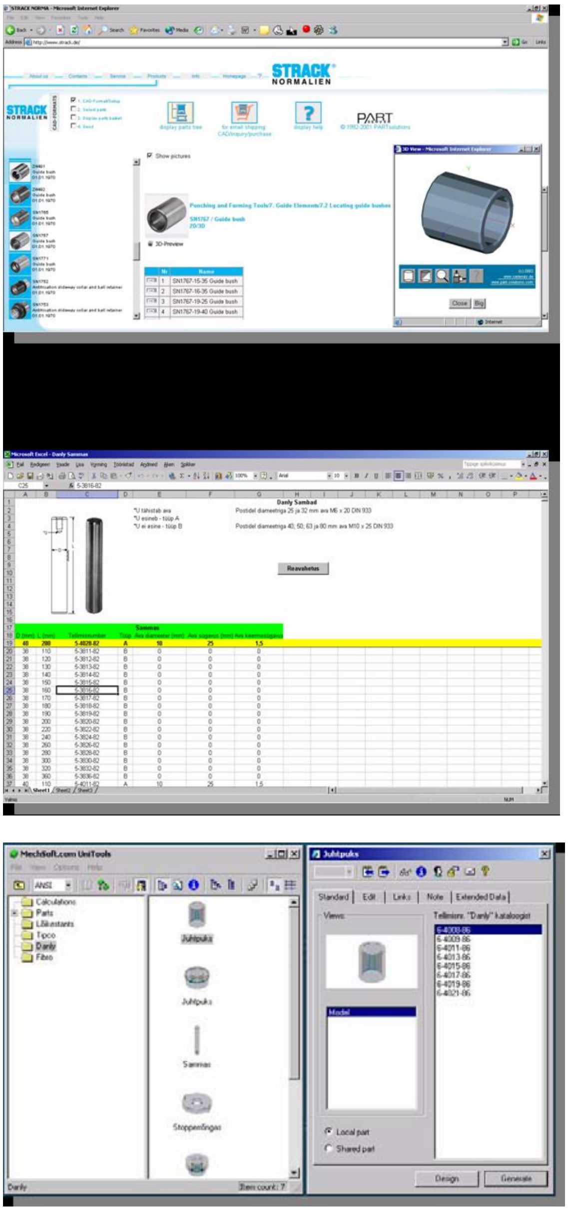

Figure 7. Example of the 3D models database for the progressive die

It is an effective and productive way to use the parametric design for the definition and modification of geometric models to implement the components of die model database.
Moreover it is a fundamental technology for efficient design of a family of die components. It involves generating new designs either by varying a standard (typical) design, or by incrementally adapting a known component model to a changed task.
In this work parametric design is utilized as a tool for geometric customization of the modules and for the realization of the database of component models.

The main problem of the development of an integrated environment for progressive cutting dies is its ability to support the design of different die components for different dies, and especially, its ability to co-ordinate these activities.
For optimal design a large number of alternative concepts should be generated for evaluation, because the selection of a best possible alternative is a crucial step in obtaining the best possible solution.

5. CONCLUSION

The challenges facing the enterprises are to implement computable methods and tools that might keep enterprise competitive and responsible to market changes on the demand of high quality and a relatively low cost. The problems of realisation of an Internet/intranet-based integrated product and manufacturing process development environment which are coupled with enterprise resource planning and management systems are described in the paper.
The basic module of DE includes midrange CAD package Solid Edge and additional module „Engineering Handbook“ or MechSoft-PROFI Unitools.
This study is apart of a larger project for the development of concurrent engineering support environment for technological equipment design.
In addition, this work doesn’t provide a representation scheme for experts to model their valuable, but difficult-to-articulate, knowledge and terms with which they are familiar yet. Therefore our future research is aimed to developing the techniques and possibilities to carry out these types of schemes.

6. ACKNOWLEDGEMENT

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