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New Methods of Designing Stamping Dies Assemblies by Using Generative Models

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Abstract. Designing stamping dies assemblies must obey strict rules and requires a lot of technological knowledge and experience. Designed dies exhibit strong similarity and the process, in spite of the complexity and the need to take into account the specifics of pressed shape, is repeatable. Therefore, the design of stamping dies assemblies can be accelerated by applying Generative Modeling method. The paper presents the process of building Generative Model of stamping dies assemblies in the environment of Siemens NX Knowledge Fusion. In addition, the paper presents a method of building a engineering knowledge base for stamping dies assemblies and the user interface for controlling elaborated Generative Model. Knowledge base and its conceptual model is adapted to acquire knowledge from experts by significantly simplifying the structure of the knowledge base and the use of common computer tools. In addition, the results of Generative Model verification and the process of improvement in the performance on the basis of practical design tasks and the introduction of changes resulting from errors that occur during verification are presented. The constructed Generative Model includes knowledge base, software written in Knowledge Fusion and the user interface. The paper also shows the benefits of using Generative Models in designing stamping dies assemblies.

Keywords. Knowledge-based Engineering, stamping dies, generative model, knowledge base, knowledge fusion

1. Introduction

While designing stamping dies a great role is played by the technological experience of a designer. Nevertheless, many parts of the newly designed die are routinely chosen and parts and subassembly are designed. In order to use technological experience of a designer it is necessary to ease him/her on routine designing tasks [1][2][3].

So far in order to speed up routine tasks commonly used CAD tools have been used and in particular catalogues of ready-made and hand-made elements as well as parametrization. The models of previously used stamping dies or their parts have also been used as a base for newly elaborated dies. It is great improvement but nevertheless, routine tasks still take up a lot of specialist's time. Therefore, a new method has been put forward which uses Generative Models for complete elimination of routine

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designing tasks. In addition, the use of this method can help with other problems occurring in die designing companies e.g.: a) standardization and die design unification in company, b) elimination of human errors in design, c) fast deployment of new designers into the design process in the company using stored knowledge and experience of older workers. This approach gives good results in case of repeated and modular designing tasks of technical systems [4][5][6][7] with specialized modules in advanced CAD systems such as Knowledgeware in CATIA or Knowledge Fusion in Siemens NX as great facilitators. However, in order to use these modules in a systematic way requires specialist skills of a designer and must be preceded by detailed overhaul of designing process and acquiring knowledge on the process and its record. Specialist methodologies [8][9] such as e.g. MOKA [2][10][11][12] together with additional tools for recording and processing knowledge are often used for that purpose, beginning with simple tools such as Excel and then proceeding to complex systems as e.g. Protege OWL [13][14][15][16] or PCPACK [2][17][18][19][20].

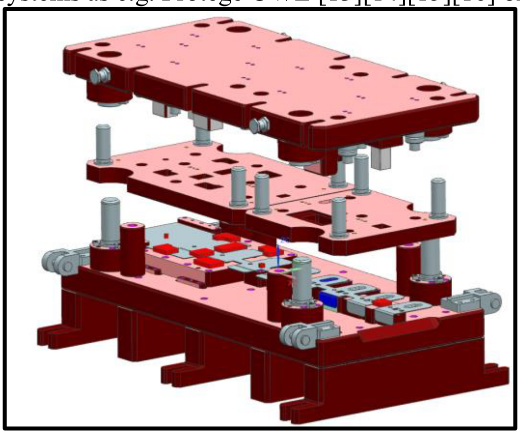

Figure 1. Multi-stage stamping die.

The use of this method for designing a multi-stage stamping die has been presented in this paper and the die presented in Figure 1 realizing nine consecutive technological operations (Figure 2) for producing an element from sheet metal.

The elaborated Generative Model should become a useful tool for everyday use for designers in a company dealing with designing stamping dies for plastic forming of sheet metal elements.

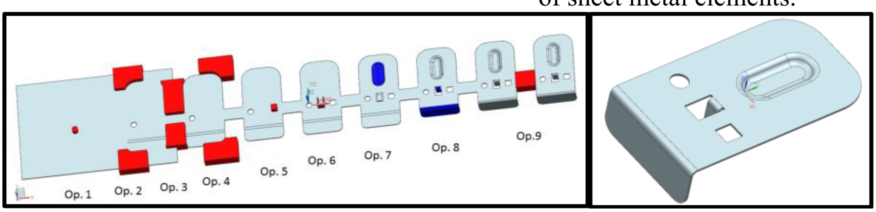

Figure 2. Plan of stamping technology and ready sheet metal element.

Due to complexity of the structure of the stamping die and Generative Models as well as protection of intellectual property the details of the model design are presented on the part of the design i.e. a subassembly of guide pillar mount unit.

2. Method of designing stamping dies based on Generative Modeling

The origin of every GM is knowledge acquisition, which is necessary for Generative model building [14][18].

Because there are many types of knowledge and many sources of knowledge, knowledge engineers developed numerous different techniques to make the process of knowledge acquisition easier. Among these many techniques of knowledge acquisition, the most popular are [1][2][10][13]; acquisition of knowledge through interviews, diagram technique of knowledge acquisition, technique of process and concept maps, backpropagation learning technique, matrix method or 20-question technique. In acquisition of knowledge for the construction of generative models, it is advantageous to use a method that is interwoven into standard operations, provides opportunities for direct control of generative model, is potentially simple, and utilizes commonly used computer tools. These possibilities are included in the method presented below.

2.1. Knowledge acquisition

Knowledge acquisition for Pillar mount unit was done using MS Excel software, that is compatible with Siemens NX [21], The complete knowledge contains:

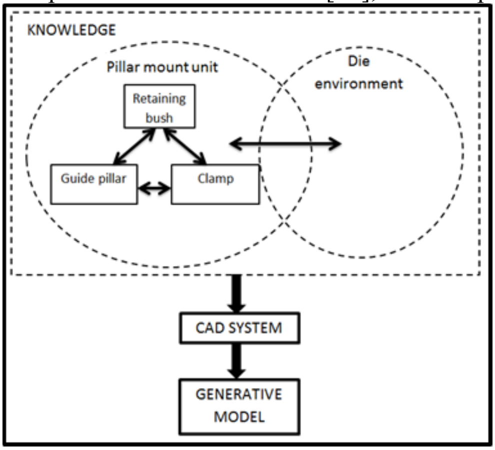

Figure 3. Structure of Pillar mount unit GM.

- All information regarding design, material and dynamic features of Retaining bush,
- All necessary catalogue data about Guide pillar and Clamps,
- Relations between all elements and design procedures,

Figure 3 shows the structure of GM for Pillar mount unit. Figure 4 shows a top-down diagram of die design, with focus on relations between elements of Pillar mount unit and influence of assembly on Die environment.

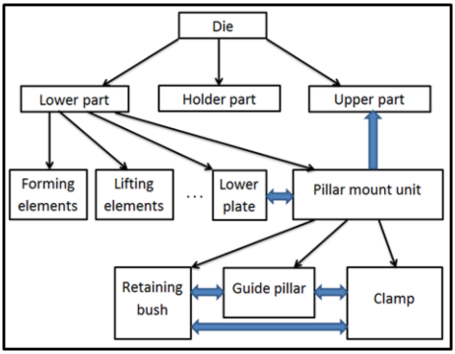

Figure 4. Die design diagram.

Underlined pointers in the diagram indicate particular relations between the elements. These relationships as well as in particular design features were defined using a dialog box in excel sheet in MS Excel. Complete design features of each unit have been recorded using separate file in MS Excel. In the created file design features of each element have been described in separate spreadsheet. Additionally, all relations between design features of every elements of unit are shown in separate spreadsheet.

Exemplary record of design features in spreadsheets is shown in Figure 5:

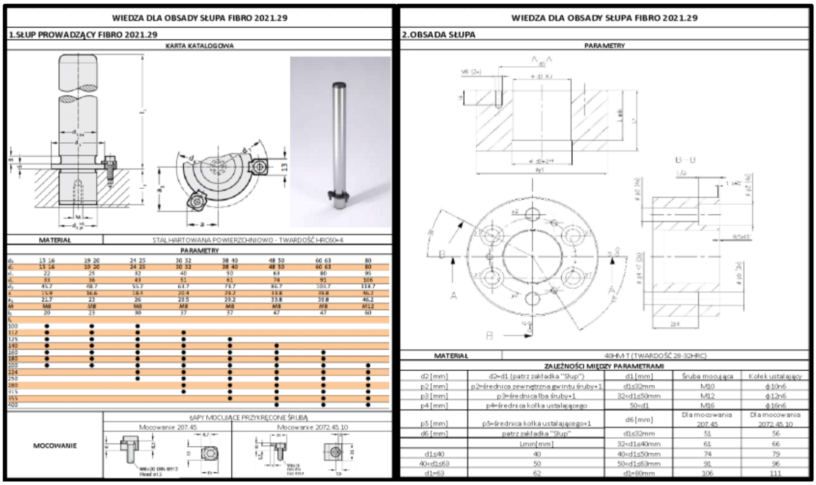

Figure 5. Tab „Guide pillar” and „Retaining bush” in design features file.

The separate spread sheet containing relations with respective controlling formulas can be found in the figure 6. It is a table that integrates all the data from spreadsheets *Guide pillar* and *Retaining bush* and contains procedures that process this data and cooperating with CAD tool.

d2	Lmin	p1	Sruba	p2	p3	Kolek	p4	p5	y1	y2	d6 dla 207.45	d6 dla 2072.45	d3	l2	M
30	40	85	M10	11	17	10	10	11	16	30	51	56	40	37	10
32	40	85	M10	11	17	10	10	11	16	30	51	56	40	37	10
38	40	92	M12	13	20	12	12	13	17	35	61	66	50	37	10
40	40	92	M12	13	20	12	12	13	17	35	61	66	50	37	10
48	50	100	M12	13	20	12	12	13	20	41	74	79	63	47	10
50	50	110	M12	13	20	12	12	13	20	41	74	79	63	47	10
60	50	130	M16	17	25	16	16	17	25	50	91	96	80	47	10
63	50	130	M16	17	25	16	16	17	25	50	91	96	80	47	10
80	62	160	M16	17	25	16	16	17	30	60	106	111	95	60	12

Figure 6. Tab „*Parameters table*”.

2.2. *Construction of the Generative Model*

To create GM model there was used „*Knowledge Fusion*” module [22]. To build models in this module the specialist Object programming language in used, as it allows to add Engineering knowledge to the element by creating suitable Rules. Rules are basic blocks creating program code of GM construction. The programming language used is declarative not procedural, what means that Rules are performed only when we refer to them or we demand performing. In addition to that in KF language we can access external knowledge base such as: Knowledge base or Spreadsheets. [22], [23]

2.2.1. Structure of the Generative Model

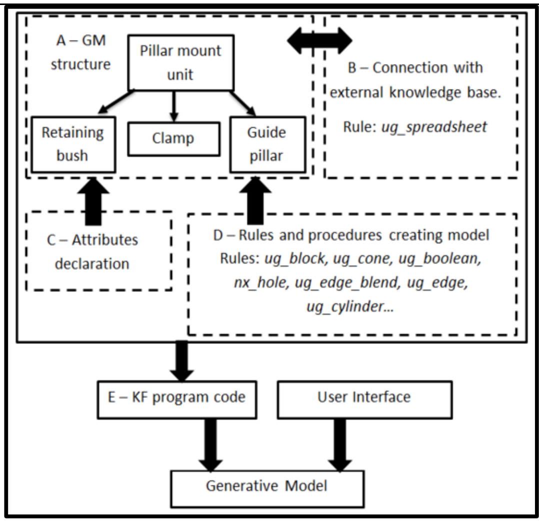

Figure 7. Creation of GM in NX Knowledge Fusion.

Stages of building the GM and its structure in NX software is shown on the diagram below (Figure 7) [21]. The example includes structure and following steps of building GM for construction part – simple Pillar mount unit. The first step to creating the model is designing right structure to a whole unit. For Pillar mounting unit the structure will consist of main file assembly and following components:

- Retaining bush,
- Clamp (there is a choice of Clamp type),
- Guide pillar,

In order to do that the following template was created: Pillar mount assembly including: retaining bush, pillar, clamping.

The structure of model should be designed in a way so that all components of assembly are controlled by corresponding Rules main assembly file.

The Rule *ug.spreadsheet* that links model with external knowledge in the Spreadsheet was entered in main assembly file in order to link GM model with external Knowledge base (Figure 8).

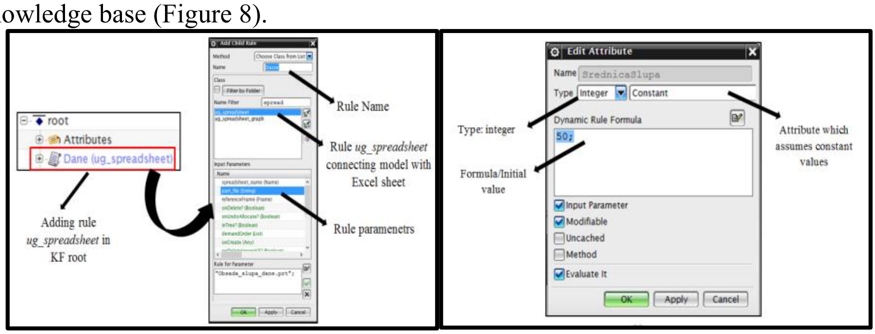

Figure 8. The Rule managing external data and PillarDimension attribute.

The next step in creating the model is inserting suitable attributes managing the model in the root of KF program of main construction file. Figure 8 also presents the exemplary declaration of an attribute in KF language. The following step in creating a GM model is creating rules responsible for particular components of assembly.

Figure 9 shows the structure of subprogram KF that generates Retaining bush geometry. Using classes: *nx_cylinder*, *ug_block*, *ug_boolean*, *ug_cone* the Retaining bush geometry was modeled referring to previously declared attributes (Figure 9). Next step in GM model creation is inserting a managing Retaining bush in main assembly – adding main program root rule *ug_child_in_part* and a rule *ug_component* generating Retaining bush (Figure 9). After having written subprograms for each components and managing them the entire code of GM model can be generated.

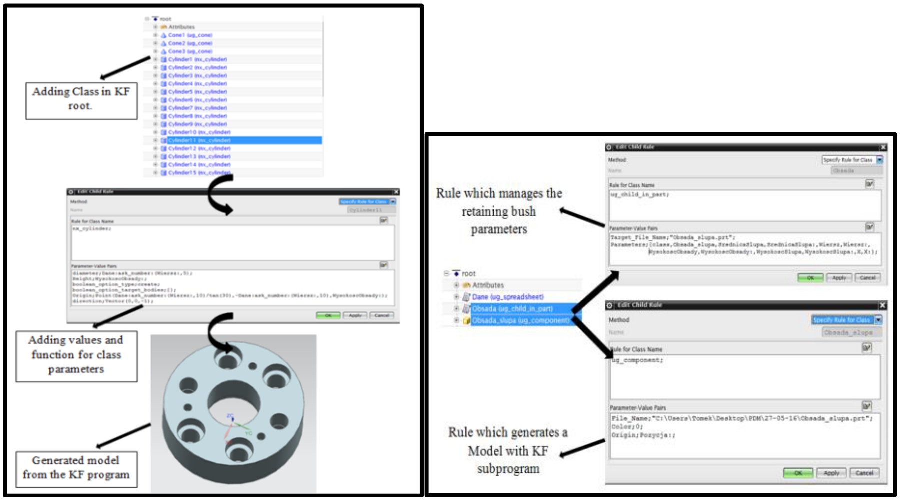

Figure 9. Retaining bush geometry (left) and rules managing retaining bush (right) in KF.

2.2.2. *User Interface of the Generative Model*

User interface of a program used to generated GM model was created in PRE-NX6 UI STYLER module. It uses previously written program code for building Generative Model of Pillar mount unit model [24]. The structure of user interface is divided into tabs regarding particular elements in assembly.

After having defined entry data according to dialog box of a program and performing calculation using knowledge recorded in database the model is generated (Figure 11).

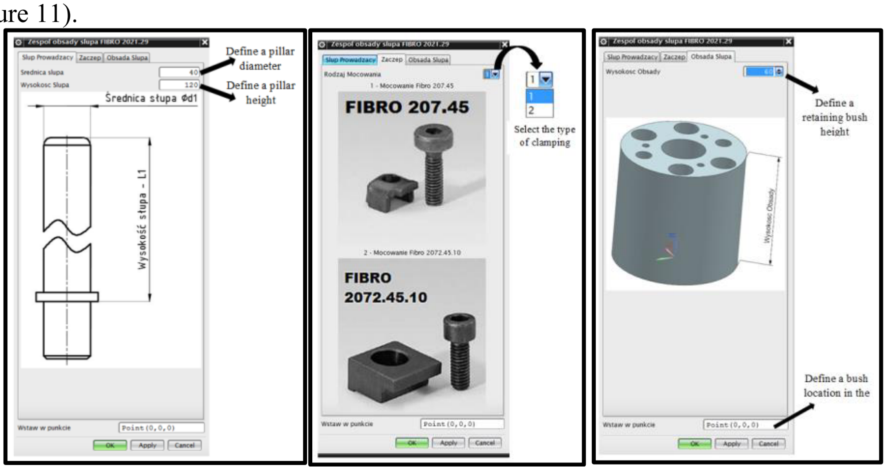

Figure 10. User Interface for Pillar mount unit GM.

2.3. *Verifiication and development of Generative Model*

The verification of the GM model was performed for 3 real cases of Die design. Each of the cases has different working parameters and functionality. For each of the verification cases there was a distinct Pillar mount unit generated using GM.

Generated model for cases A, B and C was provided in Figure 11.

During model verification some problems occurred including: lack of messages for dialog with user, lack of some dialog windows in UI. In the next versions of Generative models all problems were addressed.

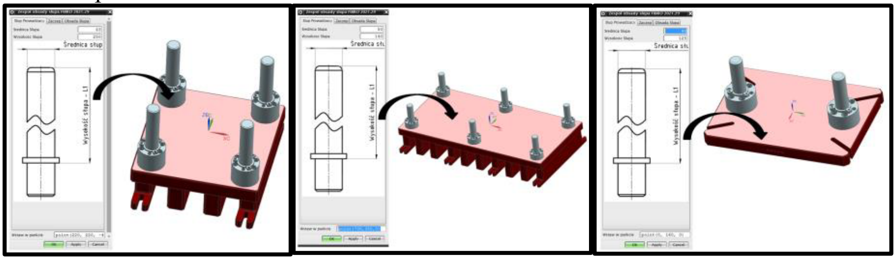

Figure 11. Verification of GM model-cases A, B and C.

3. Conclusions

The paper presents the process of creating Generative Models in the Siemens NX Knowledge Fusion environment on the example of a selected stamping die assembly.

In particular, knowledge acquisition methodology for Generative Models creation has been presented, adapted to the needs of a company specificity. It is especially beneficial to use Excel system for knowledge base creation for Generative Models since special structure of Excel sheet segregates data of particular elements and their relations. It facilitates the process of knowledge acquisition and at the same time releases a designer, who creates Generative Models, of the duty to transfer knowledge from knowledge base to Siemens NX system because the sheets are directly used for managing both model elements and their assemblies. Additional benefit of knowledge acquisition in Excel sheet is its widespread use in companies.

The knowledge base has been equipped with a suitable interface which enhances communication with the user. Additionally, Generative Model verification methodology has been pointed out, which should be extended in practice for constant improvement of these models.

Finally, the following elements constitute our Generative Models: knowledge base, CAD files, program written in KF language and user's interface.

The design of Generative Models is very beneficial for parts of structure which are of repetitive character and are designed in a routine way. Among advantages of Generative Models one can mention: a) *Significant time reduction for a designer in case of stndard designing about one hour, with Generative Models about two minutes*, b) *Reduction of routine and monotonous tasks,* c) *Possibility of faster and automated change of model parameters,* c) *Correctly designed Generative Model additionally limits possibilities of errors which are likely to occur while designing,* d) *Usefulness in standarization and unification of designing process in companies.*

Generative design also has some disadvantages associated with preparation of GM such as: a need to have a special module in your CAD system and a specialized skills to prepare Generative Model and knowledge base.

The created Generative Models of a stamping dies, presented as an example of assembly of guide pillar will be used on an everyday basis in a company which designs dies for plastic forming of sheet metal elements. Furthermore, in the future the project will be developed and next options models will be made for widening the range of applications of stamping dies.

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