PARAMETRIC MODELING AS EFFICIENT WAY OF DESIGNING

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In this article, the principle of parametric modeling as an efficient way of designing and processing technical documentation is described on the example of creating a specific parametric model.

KEYWORDS

digital manufacturing, computer modelling, parameterization, CAD software, technical documentation

1 INTRODUCTION

Customization and digitization of production processes have been characteristic of industrial production in recent years. At the same time, they indicate the basic trends in the development of industrial production in the near future, which both larger and smaller companies must necessarily follow. Gradual digitization is focused on production management, process planning, optimal technology selection and digital data analysis. Through the Industry 4.0 concept, companies create their own strategies to stay on the market and increase their competitiveness [Janosec 2017]. There is no universal guidance on when, where and how to realize the changes. In general, it is recommended, especially in small business environments, to start with smaller projects. In such a case, the likelihood of a rapid return of investments and an increase in production efficiency is higher [Pavlenko 2017a,b]. Every business must look for its own solutions and decide their own strategies for the implementing changes to production.

Company DECRAN_SK, s.r.o. is a small developing organisation. The company's production program includes safety industrial steel doors and windows. From a technological point of view, this is a simple production. The problem is to secure efficient production in the case of customized production, which represents 90% of the total production volume. Rapid production in the required quality and the operational fulfillment of different customer requirements is a necessary condition for dealing with competition on the market. A strategic plan of implementing particular changes into the production process was decided to optimize production to avoid very high costs. Because it is a small company that does not have sufficient human resources to solve the above mentioned problems, the management of the company approached to the Faculty of Manufacturing Technologies of the Technical University in Kosice, based in Presov, with a cooperation offer. A plan for the progressive automation of the whole production plant was developed. All available production data was used as input data. These business data existed in a different form but they were not analyzed. The first important step was to ensure mutual communication and exchange of information regarding all levels of the company - starting with management and ending with the distribution of finished products. The solution was to use appropriate data processing and production control software and place all data into a single, secure cloud solution. CAD software Autodesk Inventor Professional and Microsoft Dynamics NAV were purchased and put into operation. The themes, focused on the digitization of the technical documentation, the design and solution of the organizational changes and the partial solution of the automation of individual workplaces were presented as a diploma thesis options [Smeringaiova 2017a].

Data organisation and realization of their management system is the first step in Digital Manufacturing. In this case, the first step was the digitization of technical documentation. The complete drawing documentation for all types of doors and windows is continuously processed using Autodesk Inventor Professional 3D Graphics System and along with the technological procedures it is stored in the Autodesk Vault database application.

A new order acceptance system has been developed that takes the advantage of parametric product models. Universal virtual models of the basic door types will be possible to customize in the range of the defined possible changes and parameters according to customer requirements [Smeringaiova 2015 and 2017b]. Using a special user form, inputs for door height and width, type of door, door orientation and other special requirements such as special security features, handles, windows, grilles, etc. will be specified. After the generation of a customized door model, the drawings and the production process will be generated with an appropriate instructions for each operation. A new system of marking drawings and technological procedures was also developed for particualar orders.

The realization of the plan to prepare and process technical documentation using data parameterization requires expert, time and material resources that the current company does not have. Collaboration with FVT has therefore provided a solution in the form of diploma theses aimed at preparing virtual parametric models of selected products.

2 PARAMETRIC MODELING

Standard CAD programs support parametric modeling as an efficient approach to computer design. Parameterization is the way to assign different processing values to one program at different prompts. This process allows operationally configure the product design.

When designing, we often come in contact with standardized parts, respectively in the given product type with components of the same type in different variants. These vary in size, material, or other elements [Vasilko 2017, Wittner 2017]. To create them in Autodesk Inventor Professional, we use "Create Part", „Parametry" and "Author iSoupart" functions. The iSostava family (complex product model) is created, including a table listing the unique members and their variants. The table shows different data types on the tabs and columns. The individual rows represent individual members and their unique identifiers. Members can be distinguished by a single parameter or by all components in a complex configuration [Monkova 2017].

When creating a standardized component, model of a standardized product, it is recommended to follow the usual procedure :

- Component modeling.

- Named parameters in the sketch using the "Parameters" command.

- Define the number of rows in the "Author of iParts" menu, the parameters of each variant, the selection of elements and properties that change.
- Save the created component as the family component "iPart". The "Parameters" function closely specifies the inputed, connected and user parameters :
- **Model or sheet metel parameters** - displays the names and values of the parameters that were automatically generated when modeling a component.
- **User Parameters –** Defined by the user, from string to bolean types that determine the size and component elements. The user parameter can be named, define unit type, tolerance, etc.
- **Linked parameters** - displays parameter values imported from another model or from MS Excel.

Defining the 3D model parameters in the Autodesk Inventor Professional software environment is possible in three ways: using user parameters, using model dimensions or using an external table.

Chapter 3 describes the working procedure for creating a parametric model of a simple door assembly.

3 SECURITY DOOR MODEL PARAMETRIZATION

Safety type doors are manufactured in several possible alternative designs. The part of the door may or may not be a security element - a burglar protection bar with or without a padlock. The basic requirement for efficient processing of technical documentation for all possible alternatives to the type of door is a well-prepared, comprehensive model of the door assembly. The modeling of the individual components and the modeling of the door assembly had to be consistent and logical.

3.1 Analysis and identification of alternative components, shapes and dimensions of a complex model

The first step in creating parametric models is generally to identify all possible alternatives of the product outcome including all possible components, shape elements and dimensions. In the case of the door security model, eight different versions have to be considered:

1. Single door left without padlock.
2. Single door right without padlock.
3. Single door left with padlock.
4. Single door right with padlock.
5. Dobule door left without padlock.
6. Dobule door right without padlock.
7. Dobule door left with padlock.
8. Double door right with padlock.

3.2 The concept of creating a parametric model

The main assembly concept has been created :

M1 - Independent model of assembly created without burglar protection bar on the door (Fig. 1).

M2 - Independent model of burglar protection bar assembly (Fig. 2).

M1 ∩ M2 - Placing M2 do M1 complex model of main assembly is created containg burglar protection bar. (Fig. 3).

3.3 Modeling and drawing creation

Based on a detailed analysis of all possible requirements for subjected doors, individual components were standardly modelled. A complete model of door assembly without a bruglar protection bar assembly and model assembly of protection bar was developed from the components. Comprehensive models include all possible components and all possible shape elements of the individual components of the above-mentioned variant door designs. In standard mode, the drawing documentation required for production was created using the door and door assembly models as well as the components of the assembly.

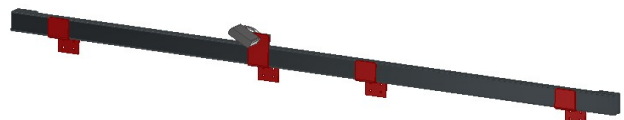**Figure 1.** Independent model of assembly created without burglar protection bar on the door

Figure 2. Independent model of burglar protection bar assembly

Figure 3. Model of the door created in Autodesk Inventor Professional

3.4 Data parametrization

Parameterization of model data of door assemblies and door burglar protection bar has created and precisely defined options for editing shape and dimensions, switching off or switching on components for those door designs. The procedure was relized as follows :

Inserting the parameters into the model environment and their application on the door assembly without the door protection bar (Fig. 1). In addition to the model parameters, user parameters were also defined.

Writing a script (model management program) using the "iLogic" function and creating user form to generate possible alternative door designs without door burglar protection.

Inserting the parameters into the model environment and their application on the model of the door burglar protection. The complex model of the door burglar protection bar assembly must include all the components of the variant door versions, with the possibility of editing their shape and dimensions, switching off or turning on their display representatin in the assembly. It is important to correctly apply the dimensions of the fitting dimensions of the shape elements from the door assembly into which the door protection bar model will be inserted. In Fig. 2 shows a complete model of a safety door bar which contains all possible door protection bar elements.

Parameters that were required to be placed into the burglar protection bar model were exported to the XML from main assembly model using the "Parameters" and "Import from XML" tools was applied to the door protection bar model. The result is the associated connection of selected parameters of the assembly and sub-assembly models, respectively component. The numerical values of the imported parameters (all dependent dimensions and shape elements) defined in the total set of doors will be also applied to the door protection bar model.

Writing a script and creating a user form to generate possible alternative versions of the door protection bar. In Fig. 4 is a listing of scripts with commands that can turon off or turn on the display of selected shape elements and components for all considered alternatives to the door design with the barrier. Each alternative has four basic parameters defined :

1. Door kind="ED", resp. "DD" – single door, resp. Double door (Pozn. : holandsky Enkele deur_ED; Dubbele deuren_DD).

2. Burglar protection="True", or "False" – model of the protection bar will be turned on or off. Functional significance of this parameter is reflected only in the model of the final door assembly on Fig. 3 after the placing protection bar into main model assembly. If the bar will be not included in the oreder then it will be possible to turn it off.

3. Burglar lock="True", or "False" – in the selected option of the model will or will not be used the security pad lock.

4. Door opening type="Left", or "Right" – it is defining the type of door opening and closing of the door. In the case of the Burglar lock="True" parameter also defined the position of the pad lock on the protection bar.

The last information is the label of the alternative generated from the capital letters of particular parameters defined in the script. For example single door left, without padlock will be labelled as SDBINNLL (single door, binnen (interior), no lock, left) [Popel 2018].

```
Dim VARBG As String

If DoorKind="ED" And Burglar_Protection="True" And Burglar_Lock="True" And DoorOpeningType = "Left" Then
VARBG="SDBINWLL"
End If
If DoorKind="ED" And Burglar_Protection="True" And Burglar_Lock="True" And DoorOpeningType = "Right" Then
VARBG="SDBINWLR"
End If
If DoorKind="ED" And Burglar_Protection="True" And Burglar_Lock="False" And DoorOpeningType = "Left" Then
VARBG="SDBINNLL"
End If
If DoorKind="ED" And Burglar_Protection="True" And Burglar_Lock="False" And DoorOpeningType = "Right" Then
VARBG="SDBINNLR"
End If
If DoorKind="DD" And Burglar_Protection="True" And Burglar_Lock="True" And DoorOpeningType = "Left" Then
VARBG="DDBINWLL"
End If
If DoorKind="DD" And Burglar_Protection="True" And Burglar_Lock="True" And DoorOpeningType = "Right" Then
VARBG="DDBINWLR"
End If
If DoorKind="DD" And Burglar_Protection="True" And Burglar_Lock="False" And DoorOpeningType = "Left" Then
VARBG="DDBINNLL"
End If
If DoorKind="DD" And Burglar_Protection="True" And Burglar_Lock="False" And DoorOpeningType = "Right" Then
VARBG="DDBINNLR"
End If
```

Figure 4. The script for the particular burglar protection bar alternatives [Popel 2018]

For each alternative of the door design, a sub-script has also been created, which defines the occurrence or suppression of individual components and shape elements for the selected alternative of the door design. In Fig. 5 there is an example of sub-script written for a door design alternative labeled DDBINWLL.

```
Select Case VARBG

Case "DDBINWLL"
Component.IsActive("Open plate:1") = True
Component.IsActive("Padlock:1") = False
Component.IsActive("Open_plate_H:1") = False
Component.IsActive("Safe_Tube:1") = True
Component.IsActive("Padlock:4") = False
Component.IsActive("Open_plate_H:4") = False
Component.IsActive("Open plate:4") = True
Component.IsActive("Padlock:3") = False
Component.IsActive("Open_plate_H:3") = False
Component.IsActive("Open plate:3") = True
Component.IsActive("Padlock:2") = True
Component.IsActive("Open_plate_H:2") = True
Component.IsActive("Open plate:2") = False
```

Figure 5. The sub-script for one of the burlar protection bar alternative [Popel 2018]

In Fig. 6 there is an example of user Form (1) with active parameters. Through the form, it is possible to manage the model, or to set up all the parameters for making the door protection barrier within the above defined options.
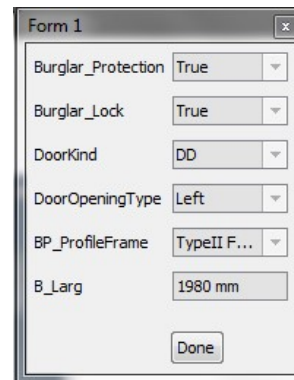

Figure 6. User form with active parameters [Popel 2018]

The application of the protection bar model in the main assembly.
The protection bar model was prepared and placed into the main assembly (Fig. 1) by standard way (ribbon „Assemble", function „Place"). The precise position of the bar in the main assembly has been defined by the constrains. The final model has been created Fig. 3, as a one complete piece. All the

parameters and setting defined in the model of the protection bar were also loaded into main door assembly. The same parameters has been unified and new ones has been added. For the case, when customer does not want to have protection bar in his order, it is necessary to add a function Burglar protection = "False" which will allow to turn off the model display representation – Fig. 7. In the model of the burglar protection bar the option– "True", or Turn on (Display) was enabled.

```
If Burglar_Protection = False Then
Component.IsActive("Binnen:1") = False
Component.IsActive("BG_Buiten:1") = False
End If
```

Figure 7. Command for turning off the protection bar assembly for the door. [Popel 2018]

Figures 8, 9, 10 show examples of alternative door designs generated by a complex parametric model.

Figure 8. Dobule door right without padlock

a)   b)

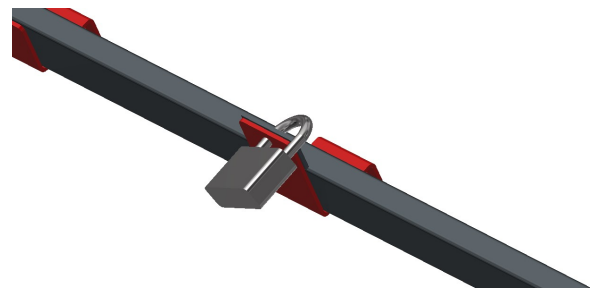**Figure 9.** Single door right a) without b) with padlock

Figure 10. Model of burglar protection bar assembly

3.5 Generation of the technical documentation with the help of parametrized model

Throught the electronic user form, all the requests for the configuration of the security door are defined containing reqested components of the door, dimensions and shape details of the particular parts. After its creation the requested model of the door is genereted adjusted regarding the configuration and alos asociative drawing is generated.

4 DISCUSSION

Parametric modeling allows effiecient way of designing and technical preparation of technical drawings for the production.

The result of the parametrization is significantelly addicted to the proper selection of working proccedures. The correct parameterization of the model guarantees the changes in shape and dimensions without any complications. In addition

To the knowlage of the graphical software, the practical experience and adherence to certain principles of work are very important :

-    In the model modeling process is repeatedly presented the goal to figure out as many shape changes as possible in one shape element. The result of complex sketches is complicated final form of the model in one view. It is more efficient to replace complex geometry with multiple simpler shape elements. Then, the necessary changes can be made via editable and geometric groups.

-    If possible, the individual shape elements of the model need to be modeled independently regarding the other elements. Their shape and position should refer to working planes, axes, points.

-    An important element of parametric modeling is associativity. This feature provides a link between the model, assembly, drawing and CAD / CAM system as well as the NC program. Its functions are significant in the subsequent

modifications of the already created model, and all changes are reflected in the downstream parts of the design such as assembly or drawing documentation. If associativity works properly, it will be reflected in a fully-prametirzed sketches [Wittner 2017].

- The hierarchical structure of the model components in the element tree must be consistent with the actual product structure according to the technological and installation procedures.

- It is also important to monitor the development of supplementary products supporting parameterization. For example, iFX services develops an automation module as an extension of Autodesk Inventor Professional. "IFX_Services Add-in" is a general automation and parameterization tool that collaborates with iLogic for autonomous digital prototypes. This tool has generic autonomous functions that ensure the functioning of automated virtual models, but basic logic and unique user environment are programmed in a native digital prototype environment for each product individually, prepared to each specific customer according to their needs [iFXservices 2018].

5   CONCLUSIONS

Digital Manufacturing represents the use of an integrated computer system that includes simulations, three-dimensional (3D) visualization, analysis, and various tools to collaborate on product design and production process management at the same time. Most companies are aware of the importance of digitization. By introducing digital elements into production processes and devices, they significantly improve the utilization of production facilities, human resources and spending.

In the example, the parametric model of the security door is described by the principle of parametric modeling. This efficient construction method allows you to respond operatively to structural changes and modifications of manufactured products to customer requirements. The article is also a guide for smaller companies, as lack of their own expertise sources can be managed with co-operation.

REFERENCES

[iFXservices 2018] iFXservices [online]. [2018-05-28]. Available at: http://ifxservices.com (in Slovak)

[Janosec 2017] Janosec, J. et al. Influence of digital platforms on the european industry and policy making. MM Science Journal, Vol. 2017, No. November, pp. 1869-1872. ISSN 1803-1269.

[Monkova 2017] Monkova, K. and Smeringaiova, A. Step by step in the software Inventor Professional. Prague, RISE, 2017, 178 p. ISBN 978-80-87670-20-0. (in Slovak)

[Pavlenko 2017a] Pavlenko, S. Design and check of the mechanical components by the PC application. MM Science Journal, 2017, No. December, pp. 1914-1918. ISSN 1803-1269.

[Pavlenko 2017b] Pavlenko, S. Design of a program for calculation of forcing spring stiffness. MM Science Journal, 2017, No. December, pp. 1924-1928. ISSN 1803-1269.

[Popel 2018] Popel, D. Parametrization of product model. Diploma work, 2018, FMT TUKE, Presov (in Slovak)

[Smeringaiova 2015] Smeringaiova, A., Vojtko, I., Monkova, K. Experimental analysis of gearbox dynamics - part 2. TM-Technisches Messen, 2015, Vol. 82, No. 4, ISSN 0171-8096 (in German)

[Smeringaiova 2017a] Smeringaiova, A. and Pavlenko, S. Implementation of CA – technology in teaching: Computer aided design. In: DIDMATTECH 2017. Trnava: University in Trnava, 2017, pp. 126-134. ISBN 978-80-568-0029-4

[Smeringaiova 2017b] Smeringaiova, A. and Murčinková, Z. Computer aided educational process in the design of technical systems. In: EPF 2017, Hradec Kralove: Magnanimitas, 2017, pp. 288-295. ISBN 978-80-87952-21-4

[Vasilko 2017] Vasilko, K. and Murcinkova, Z. The proposal how to make the basic machining technologies - turning, milling, planing - more productive. Manufacturing Technology, 2017, Vol. 17, No. 2, pp. 261-266. ISSN 1213-2489

[Wittner 2017] Wittner, M. Automation and parameterization in industry [online]. [2017-05-28]. Available at: http://ifxservices.com (in Slovak)

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