

Product Platform for Automatic Configuration of Modular Strongrooms

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Abstract: Modular strongrooms (MSR) consist of industrially made elements, which are assembled at the place of use. They are designed on individual customer's requests. The customer chooses the resistance grade according to EN 1143-1 standard and provides dimensions of the available space for requested product to be fit in. Configuration of MSR is realized by combining standard modules which are, for the selected resistance grade, repeated in each new project, and differ only by their number and dimensions. This paper presents product platform developed for automatic MSR configuration, based on parametric and variable design, which provides requested configuration of the product, eliminates possible errors in design process, provides requested product quality level, decreases design and manufacturing costs, shortens design time and provides faster response to customer's requests. The proposed concept is tested and confirmed on numerous examples of realized projects.

Keywords: automatic configuration; CAD 3D; modular design; modular strongroom; parametric design; variable design

1 INTRODUCTION

Increasing global market competition demands of a product to meet a number of conflicting requests: to be adjusted to customer's needs and requests, to be functional, to have high quality, to be economical in exploitation, to be ecologically suitable and to be produced in the shortest possible time. Mass production of identical products is overcome production system, and modern market requirements led to introducing the strategy of mass customization [1, 2]. The approach is based on the idea of producing highly variant products which meet individual requests of clients, with production costs near to mass production costs [3, 4].

In order to provide sufficient product variation and to achieve cost-effective production, the companies are increasingly investing in the design and development of product family [5] i.e. a group of related products derived from a common production platform [6, 7]. As a configurable product architecture, modular architecture is the most commonly used. The product is decomposed into functional modules whose selection and combination can be used to configure product variants within the product family [8] to meet different customer requirements.

The product configuration process task is reduced to the selection of product elements from the given set, to form a product variant that meets the customer's requests while respecting the known rules and constraints between the selected elements and modules [9].

Modern configuration systems provide a number of advantages [3, 10]:

- the ability to meet a larger number of customer requirements,
- successful implementation of mass customization,
- shortening the time of product appearance on the market,
- costs reduction,
- a variety of products are offered,
- shorter delivery cycles of product variants,
- users are integrated into the design process, etc.

Strongrooms are complex and very demanding engineering objects that need to satisfy a multitude of different and often controversial demands [11]. Every MSR essentially represents a new product which should be integrated into the dimensions set in advance. It requires repetition of all phases of the design process for each MSR.

The classical design methods are rather slow and frequent errors in the design documentation are manifested in the process of construction of certain modules, and particularly in the process of assembling strongrooms [12].

The aim of the paper is to present the possibility of automatic configuration of rectangular strongrooms based on the modular structure for a quick response to individual customer's requirements and assurance of high quality products.

The other chapters are organized as follows: In Section 2, the definition, description and purpose of the MSR, the classification of the resistance grade and the basic characteristics of the MSR type "Modulprim" are given. Part 3 is an elaborate of automatic configuration platform of MSR. Section 4 discusses the implementation of the proposed platform. Section 5 gives concluding considerations and a plan for further research.

2 MODULAR STRONGROOMS

Strongroom is a room with special security features and is intended for keeping money, valuables, confidential documents etc. Users of the treasury facilities are bank institutions, post offices, governments and state authorities, military and police organizations, pharmaceutical companies, industrial companies, etc.

The basic function of a strongroom is to fulfill the security features, meaning that it is resistant to attack by invasive tools (safe from burglary), fire resistance, resistance to different kinds of radiation as well as safety from flood, i.e. water penetration.

A strongroom usually has four walls, a floor and a ceiling. Like every other room it has a door, usually one, and in exceptional cases two or more. In addition to door openings, there are other openings in the wall (floor and ceiling): for natural or artificial ventilation, for electric conductors, for telecommunication and computer connection, for conductors of anti-burglary devices and for automated input and/or output of things [11].

2.1 Purpose and Description of MSR

Given that the classical way of building the strongrooms is expensive and long, the modular structure of the strongrooms is becoming more and more important. Modular strongrooms are made at the customer's request. He selects the resistance grade and provides the available

dimensions of the space in which this product is to be installed. The basic advantages of the modular building of the strongrooms are [11]:

- thin walls ensure large useful space volume,
- the possibility of placing a strongroom in the higher floors of a new buildings or the reconstruction of an already existing room in the strongroom,
- the modules of the strongrooms are connected by welding, which provides compactness to the facility,
- a short time of construction of strongroom.

The modular construction of the strongrooms is the construction system of industrially manufactured modules that are assembled at the site of use. Individual modules (wall, floor and ceiling) are entirely manufactured by safety equipment manufacturers, and then transported to the place of use where they form a MSR. The closing part of the strongroom in the modular construction is the door embedded in the door frame. The door frame is also manufactured by safety equipment manufacturers and is usually the same as in mass construction. The layout and basic elements of the MSR are shown in Fig. 1 [13].

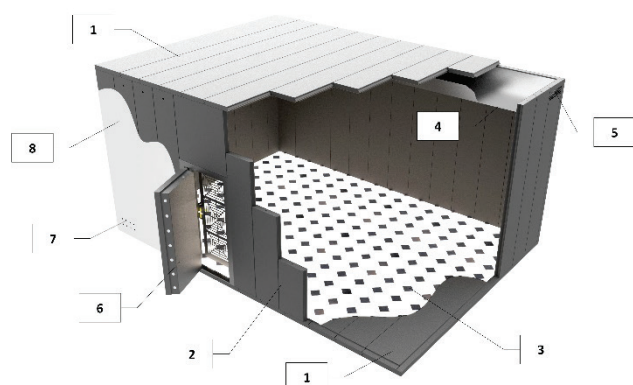


Figure 1 Modular strongroom: 1 - ceiling (floor) elements, 2 - safety wall elements, 3 - internal cover plates, 4 - cable lines, 5 - ventilation system, 6 - strongroom door, 7 - aeration, 8 - external cover plates [13]

Modular strongrooms are usually rectangular, since it is the easiest shape to produce. However, rectangular shapes are not exclusively used [11, 14]. Shapes consisted from multiple rectangulars are often produced, while rooms with rounded or sloped walls are not desirable.

2.2 Resistance Grade of Strongroom-European Standard

The basic function to be completed by the faces of the strongroom (wall, floor and ceiling) and the strongroom door is a burglary resistance, the resistance to attack by invasive tools. European standard EN 1143-1 [15] gives a range of resistance grades of strongrooms from 0 to XIII measured in resistance units (RU). The CD option - an attack with tools made from hard metal plates is not designed for 0 to IV resistance grades either in strongrooms or in strongroom doors, while the Ex - explosive attack option is not provided for resistance grades 0 and I.

2.3 Modular Strongrooms "Modulprim"

Company "Primat" a.d. Maribor produces modular strongrooms "Modulprim". The strongrooms are tested in the accredited Verband der Schadenversicherer Köln laboratory (Germany) and have the necessary certificates.

All modules are connected together by welding, which is very convenient from the static standpoint. The calculation is made so that the strongroom ceiling in modular construction, in addition to its weight, must carry an additional surface load of up to 300 dN/m² in the range between 3,0 to 6,4 m walls, without special substructure or additional lifting beams. This is indispensable in cases when the strongrooms are subsequently set up in the office premises or bank hollies. The thickness of the wall, floor and ceiling of the MSR is, on average, two to five times smaller than the wall thickness of the strongrooms in mass construction. Consequently, MSR weights are proportionally less.

Below, a platform for configuring MSR of "Modulprim" type from the production program of "Primat" a.d. Maribor is presented.

3 PLATFORM FOR AUTOMATIC CONFIGURATION OF MSR

A product platform can be defined as a "set of agreements on the components and relations out of which a product variant will be composed" [16]. According to [17, 18] "a product platform is a set of subsystems (components, modules, or parts) and interfaces that form a common structure from which a stream of derivate products can be efficiently created and launched". Robertson and Ulrich [7] consider product platform as a "collection of assets (components, processes, knowledge, people and relations) that are shared by a set of products".

Since the product platform is the basis for the development of configurable products, the purpose of this paper is to develop a platform based on which the MSR family configuration model that needs to have the following properties, can be defined [19]:

- the product must have a pre-designed general structure for the entire family of products,
- the product should be designed to meet different customer requirements within a certain range,
- each individual product is formed from a set of already designed components and modules without the need to design new components,
- each individual product is tailored to individual customer requirements.

Within the development of the MSR configuration platform, a set of modules and a set of requirements and constraints are defined, module connections are standardized and configuration rules are defined.

3.1 Set of Requirements and Constraints

In order to make the configuration of the MSR it is necessary to observe: 1. Customer requirements, and 2. Technical and technological constraints.

When ordering the product, a customer defines:

- the resistance grade of the strongroom according to EN 1143-1,
- strongroom shape,
- available dimensions in which the strongroom is set and load per m²,

- number, dimensions, resistance grade and type (left or right) of the strongroom doors, as well as position of the doors in the strongroom,
- special requirements such as: need for ventilation, aeration, additional installations, etc.

Basic rules for configuring MSR are largely determined by customer's requirements. The choice of the resistance grade of the strongroom according to EN 1143-1 defines the thickness of the wall of the "Modulprim" strongroom, internal structure and module filling.

The most common need is for rectangular form of a strongroom. However, in some situations, the customer may require even more complicated forms, depending on the available space in which the strongroom is setting up.

Depending on the length and width of the strongroom, the layout direction of the floor and ceiling modules is defined.

For larger strongrooms requiring a module length greater than 6m, it is mandatory to use the supporting substructure.

Strongroom doors are ordered independently of the strongroom. However, for the configuration of a modular strongroom, the basic dimensions of the strongroom door, their position in the strongroom and the direction of opening are needed. Depending on the direction of opening (left or right), the method of the modules connection is different, and thus the direction in which the whole room is formed (from the left to the right or the opposite).

Depending on the specific customer's requirements, the number and position of the openings for the additional installations in the modules of the strongroom are defined.

For the purpose of this paper, technical and technological constraints that have been considered are limited to the MSR that are most commonly used, namely rectangular MSR with a single door and no additional substructure support. The following limitations were adopted for configuration:

- rectangular shape of MSR,
- maximum module length $l_{max} = 6000$ mm,
- standard module width $b = 550$ mm,
- minimum module width $b_{min} = 400$ mm,
- maximum module width $b_{max} = 850$ mm,
- minimum technological distance between strongroom door and left side of the room $D_{min} = 400$ mm,
- minimum height must be equal to or greater than strongroom door height $C_{min} \geq F$,
- MSR height has to fulfil the condition $C_{max} \leq 6000$ mm.

3.2 Set of Modules

The most important feature of MSR architecture is its modularity. The family of these products is created from a common set of components i.e. modules that have a number of common features. The modularity of the strongroom is realized by the principle of *sectional modularity* and *cut-to-fit modularity* [1, 20÷22]. *Sectional modularity* is used to form the product structure by linking the modules over identical interfaces (connections). All modules are defined parametrically so that the dimension variation of the module achieves customization of the product to the given dimensions.

Classification of modules for configuring MSRs is shown in Tab.1. The layout and position of the module in the strongroom according to the adopted classification is shown in Fig. 2.

Table 1 Module classification [14]

Criterion		Module types							
I	Function	Basic modules			Connecting modules				
II	Type (shape)	A	D	B	C	E			
III	Width	S	NS	S	S	NS	NS	NS	
Designation		A	A1 A2 A3 A4	D	B	B1 B2 B3	C	C*	E
Legend: S - standard module width, NS - non-standard									

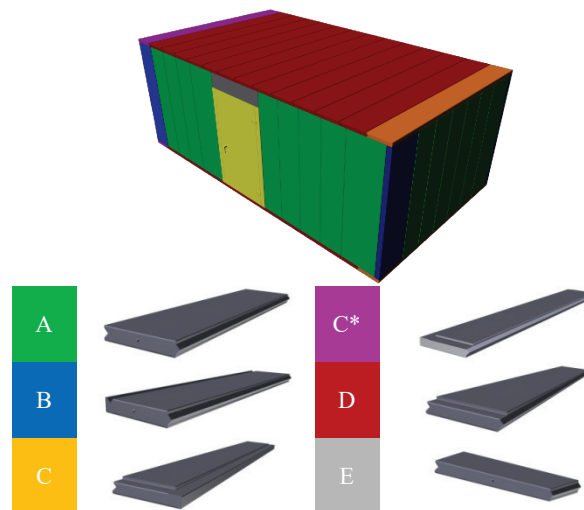


Figure 2 Module types

3.3 Standardized Connectors for Mounting Modules

There are also well-designed connections for assembling the modules to form the MSR. All the individual modules are welded to the other modules with which they are in contact, providing the unbreakable connection that gives additional rigidity of MSR and additionally provides anti-burglary resistance. Six different variants of the module joining are standardized (Fig. 3).

3.4 Rules for Configuring MSRs

3.4.1 MSR Configuration Procedure

Configuration of MSR consists of 4 different building blocks: 1. front wall, 2. side walls, 3. back wall and 4. floor and ceiling. The procedure for configuring the MSR is shown in Fig. 4. It consists of the following:

- Floor (bottom) is formed from modules C*, D and C.
- Front wall is formed of two areas: the area left to the door consisting of modules B1, A and A1, the area right of the doors, consisting of modules A and A2, and the strongroom door and module E located between these two areas. The front wall is connected to the side walls with modules B1 and B2 and it is connected to the floor with all floor modules.
- Right and left side walls are formed of modules B2, A and A3. Right wall is connected to front and back wall with modules B2 and B3, and it is connected to the floor with module C. Left wall is connected to front

and back wall with modules B1 and B2 and it is connected to the floor with module C*.

- Back wall is formed of modules B3, A and A4. It is connected to side walls with modules B2 and B3 and it is connected to the floor with all floor modules.
- Ceiling is formed at the last of the same modules as the floor: C*, D and C. It is connected with all modules which form strongroom walls.

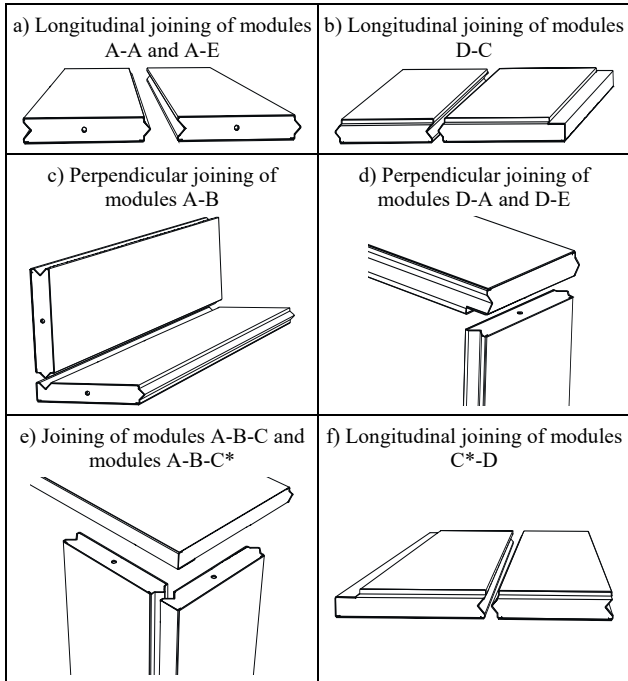


Figure 3 Module joining types

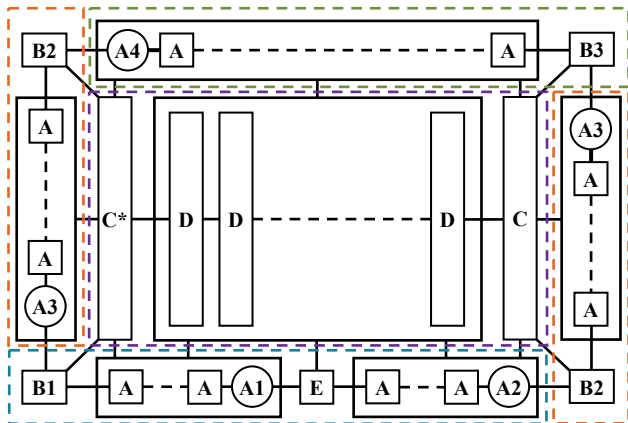


Figure 4 The scheme of the MSR configuration procedure

3.4.2 Calculation of the Basic Parameters of Module

The most demanding and most responsible job in configuring the MSR is the calculation of the parameters of the individual modules as well as the number and arrangement of the same [12, 14]. To calculate the module parameters, *MS Excel* was used for ease of calculation and ability to embed logic functions.

In *MS Excel*, the basic dimensions of the MSR (length *A*, width *B* and height *C*), the size of the strongroom door (width *E* and height *F*) and distance from door to the left wall of strongroom *D* are entered based on the size of the available space in which the buyer wants to set up the modular strongroom, and the requested resistance grade

according to EN 1143-1 is entered as well (Fig. 5). The thickness of the module (*d*) is determined by the choice of resistance grade.

The basic parameters and structure of the building blocks are shown in Fig. 6 and determined according to Eq. (1)÷(5).

ENTER DATA			
Dimensions of the strongroom	Length	A=	7050 [mm]
	Width	B=	3800 [mm]
	Height	C=	3000 [mm]
Strongroom door	Door distance from the left side of the wall	D=	1800 [mm]
	Width	E=	1400 [mm]
	Height	F=	2200 [mm]
Resistance grade (EN 1143-1)			VI

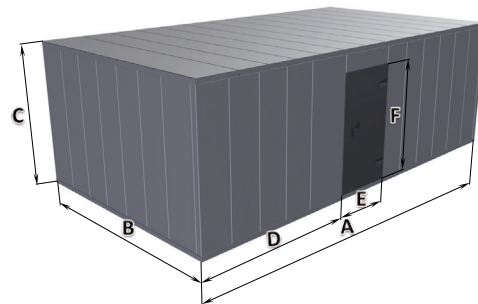


Figure 5 Basic dimensions of MSR "Modulprim" [14]

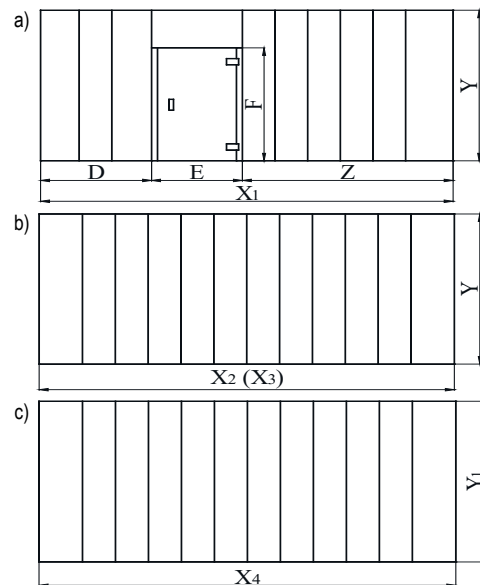


Figure 6 Basic parameters of: a) front wall, b) side and back walls, c) floor and ceiling

$$X_1 = A - d \tag{1}$$

$$Y = C - 2 \cdot (d - 20) \tag{2}$$

$$Z = X - D - E \tag{3}$$

$$X_2 = B - d \tag{4}$$

$$X_3 = A - d \tag{5}$$

where are: height of the walls (*Y*), length of the front wall (*X₁*), length of the wall right to the door (*Z*), length of the side walls (*X₂*) and length of the back wall (*X₃*).

The rule is that the floor and ceiling modules are placed so that their length is in the direction of the shorter wall of MSR. Parameters: length of the floor (ceiling) (*X₄*)

and width of the floor (ceiling) (Y_1) are calculated as follows:

$$X_4 = \begin{cases} A; \text{if } (B \leq A) \\ B; \text{otherwise} \end{cases} \quad (6)$$

$$Y_1 = \begin{cases} B; \text{if } (B \leq A) \\ A; \text{otherwise} \end{cases} \quad (7)$$

Further calculation procedure requires that all walls and segments should be split to standard module widths ($b = 550$ mm) and that also maximal number of standard width modules (k) as well as remaining wall dimensions (m) should be calculated.

Table 2 Calculation of parameters k and m

	Front wall		Other walls, floor (ceiling)
	Left to the door	Right to the door	
k	$= \text{INT}(D/550)$	$= \text{INT}(Z/550)$	$= \text{INT}(X_i/550)$
m	$= (D/550 - k) \times 550$	$= (Z/550 - k) \times 550$	$= (X_i/550 - k) \times 550$

The basic module's parameters that need to be calculated are the number of modules (n), the width of the module (b_i) and the length of the module (l).

According to given basic dimensions of the MSR, parameters calculated using Eq. (1)-(7) and rules defined in Eq. (8)-(19), basic parameters of each module are calculated. Rules used for calculation of basic parameters of the front wall module left to the door ((Eq. (8)-(12)), front wall module above the door ((Eq. (13)-(15)) and front wall module right to the door (Eq. (16)-(18)) are shown. The rules for calculation of basic parameters for other modules are defined in the same way.

$$b_{B1} = \begin{cases} D; \text{if } (400 \leq D \leq 850) \\ D/2; \text{if } (850 < D \leq 950) \\ (550 + m)/2; \text{if } (D > 1500 \text{ and } 300 < m \leq 400) \\ m; \text{if } (D > 1500 \text{ and } m > 400) \\ 550; \text{otherwise} \end{cases} \quad (8)$$

$$n_{B1} = 1 \quad (9)$$

$$n_{A_{\text{Left}}} = \begin{cases} 0; \text{if } (400 \leq D \leq 1500) \\ k - 2; \text{if } (D > 1500 \text{ and } m \leq 300) \\ k - 1; \text{if } (D > 1500 \text{ and } 300 < m \leq 400) \\ k; \text{otherwise} \end{cases} \quad (10)$$

$$b_{A1} = \begin{cases} 0; \text{if } (400 \leq D \leq 850) \text{ or } (D > 1500 \text{ and } m > 400) \\ D/2; \text{if } (850 < D \leq 950) \\ D - 550; \text{if } (950 < D \leq 1400) \\ (D - 550)/2; \text{if } (1400 < D \leq 1500) \\ 550 + m; \text{if } (D > 1500 \text{ and } m \leq 300) \\ (550 + m)/2; \text{otherwise} \end{cases} \quad (11)$$

$$n_{A1} = \begin{cases} 0; \text{if } (400 \leq D \leq 850) \text{ or } (D > 1500 \text{ and } m > 400) \\ 1; \text{if } (850 < D \leq 1400) \text{ or } (D > 1500 \text{ and } m \leq 400) \\ 2; \text{otherwise} \end{cases} \quad (12)$$

$$b_E = E \quad (13)$$

$$l_E = Y - F \quad (14)$$

$$n_E = 1 \quad (15)$$

$$n_{A_{\text{Right}}} = \begin{cases} 0; \text{if } (400 \leq Z \leq 950) \\ 1; \text{if } (950 < Z \leq 1500) \\ k - 1; \text{if } (Z > 1500 \text{ and } m \leq 400) \\ k; \text{otherwise} \end{cases} \quad (16)$$

$$b_{A2} = \begin{cases} Z; \text{if } (400 \leq Z \leq 850) \\ Z/2; \text{if } (850 < Z \leq 950) \\ Z - 550; \text{if } (950 < Z \leq 1400) \\ (Z - 550)/2; \text{if } (1400 < Z \leq 1500) \\ 550 + m; \text{if } (Z > 1500 \text{ and } m \leq 300) \\ (550 + m)/2; \text{if } (D > 1500 \text{ and } 300 < m \leq 400) \\ m; \text{otherwise} \end{cases} \quad (17)$$

$$n_{A2} = \begin{cases} 1; \text{if } (400 \leq Z \leq 850) \text{ or } (950 \leq Z \leq 1400) \text{ or } \\ (Z > 1500 \text{ and } m \leq 300) \text{ or } \\ (Z > 1500 \text{ and } m > 400) \\ 2; \text{otherwise} \end{cases} \quad (18)$$

$$l_A = l_{A1} = l_{A2} = l_{B1} = Y \quad (19)$$

4 IMPLEMENTATION OF THE PROPOSED CONFIGURATION MODEL

Automatic configuration of MSR is implemented using CAD software *Autodesk Inventor* and consists of the following stages:

- parametric design of module parts,
- parametric design of the modules,
- automatic configuration of CAD3D model of MSR based on variant design.

At this stage, special attention is paid to the quality of the CAD model and the design process as they are crucial to the overall quality of the final product.

4.1 Parametric Design of Parts

Modern 3D CAD software supports parametric design as well as the ability to prepare and input parameters from the other software [12, 23]. In this paper, *Autodesk Inventor* CAD software integration with *MS Excel* has been implemented. All modules are parametrically modelled in *Inventor* based on parameters computed and imported from *MS Excel*. The parameters on the basis of which the geometric shape of the parts is modelled are linked by a series of relationships and are calculated algebraically. For each new product, the CAD 3D model of part is adjusted based on new parameter values. This automates the process of repetitive parts design, eliminates errors and reduces time and costs [24, 25].

Fig. 7 shows an example of the parameters calculation for the shell of module A1 and corresponding CAD 3D model in the *Inventor* is presented in Fig. 8.

Since the documentation is necessary for the production but also for further development of the product configuration system (PCS) especially in companies that produce complex products [26, 27] an automated document generating system was also developed from the configuration model to obtain reliable documentation without technical errors.

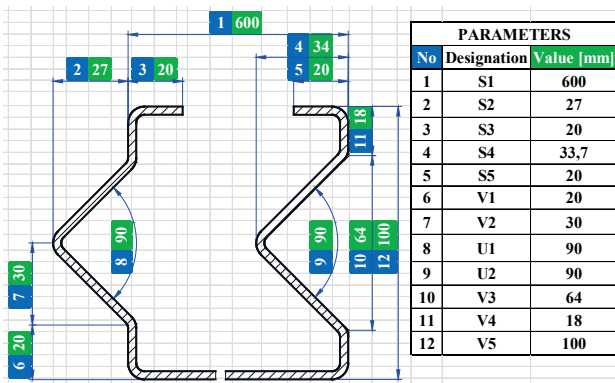


Figure 7 Calculation of shell elements of module A1 in MS Excel

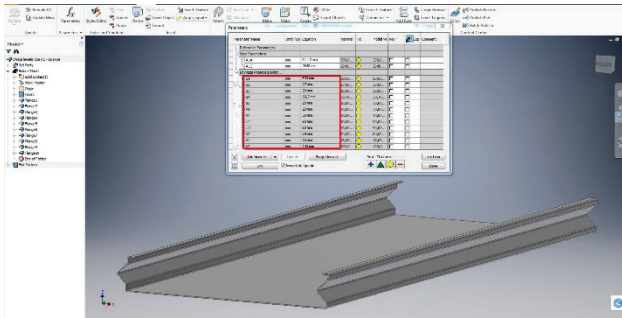


Figure 8 Parameters import and parametric modelling of module's A1 shell in Inventor

4.2 Parametric Design of Modules

Based on customized CAD 3D models of all parts, from which modules are built and calculated geometric parameters imported from MS Excel, Inventor automatically adjusts CAD 3D models of modules with corresponding assemblies and subassemblies. An example of the calculation of dimensional parameters of module B is shown in Fig. 9.

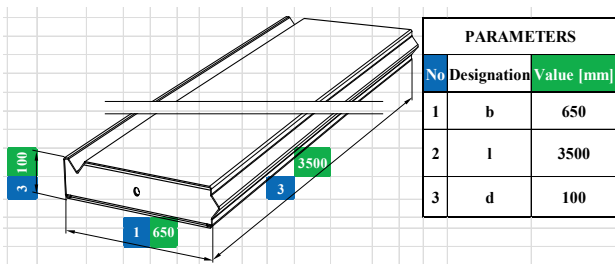


Figure 9 Calculation of parameters of module B in MS Excel

A system for automatic generation of documentation from a configuration model has also been developed for all modules.

4.3 Design of MSR 3D Model

Automatic configuration of the CAD 3D model of MSR is realized by combining the CAD 3D models of the module according to the rules defined in section 3.4. Module management is done using *InventorLogic* plug in for variable design. The values of the parameters needed to form 3D model of assembly are also calculated in MS Excel and imported into *iLogic* where, based on the configuration rules, programming codes are written to define the arrangement and number of modules per strongroom wall, their orientation and positioning. As a result, on the computer screen, a complete CAD 3D model of MSR assembly is presented, which is done in accordance with defined requirements and constraints (Fig. 10).



Figure 10 3D CAD assembly of MSR

In the *iLogic* module, the following problems are programmed:

- The direction of laying floor and ceiling modules in accordance with Eq. (6) and Eq. (7) (Fig. 11 and 12).
- Arrangement of the required number of modules per MSR wall as well as disabling modules that do not appear in a particular configuration (if number of modules is equal to zero) (Fig. 13).

```

IfParameter("FLOOR")=0 ul Then
    Constraint.IsActive("Flush:43")= False
    Constraint.IsActive("Flush:38")= False
    Constraint.IsActive("Flush:37")= False
    Constraint.IsActive("Flush:60")= True
    Constraint.IsActive("Flush:59")= True
    Constraint.IsActive("Flush:58")= True
Else
    Constraint.IsActive("Flush:43")= True
    Constraint.IsActive("Flush:38")= True
    Constraint.IsActive("Flush:37")= True
    Constraint.IsActive("Flush:60")= False
    Constraint.IsActive("Flush:59")= False
    Constraint.IsActive("Flush:58")= False
EndIf
    
```

Figure 11 The code in *InventorLogic* to determine the direction of floor and ceiling modules

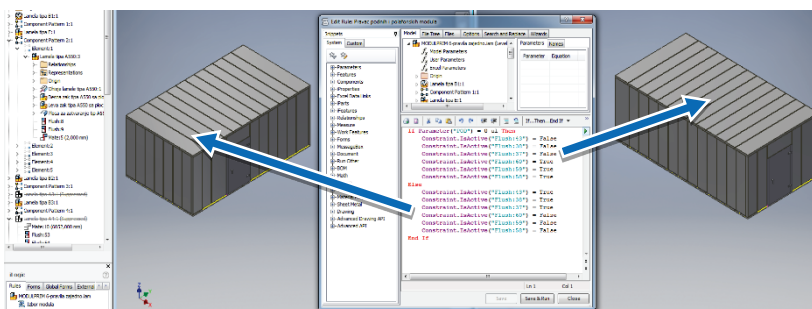


Figure 12 Code application in *InventorLogic* and corresponding result

```

"Front wall - selection of module left to the door
IfParameter("nA-left")=0 ul Then
  Component.IsActive("Component Pattern 1:1")= False
  Constraint.IsActive("Mate:2")= False
Else
  Component.IsActive("Component Pattern 1:1")= True
  Constraint.IsActive("Mate:2")= True
EndIf
IfParameter("nA1")=0 ul Then
  Component.IsActive("Component Pattern 8:1")= False
  Constraint.IsActive("Mate:3")= False
Else
  Component.IsActive("Component Pattern 8:1")= True
  Constraint.IsActive("Mate:3")= True
EndIf
"Front wall - selection of module right to the door
IfParameter("nA-right")=0 ul Then
  Component.IsActive("Component Pattern 2:1")= False
  Constraint.IsActive("Mate:5")= False
Else
  Component.IsActive("Component Pattern 2:1")= True
  Constraint.IsActive("Mate:5")= True
EndIf
IfParameter("nA2")=0 ul Then
  Component.IsActive("Component Pattern 9:1")= False
  Constraint.IsActive("Mate:6")= False
Else
  Component.IsActive("Component Pattern 9:1")= True
  Constraint.IsActive("Mate:6")= False
EndIf
"Side walls
IfParameter("nA3")=0
  Component.IsActive("Module type A3:1")= False
  Component.IsActive("Module type A3:2")= False
  Constraint.IsActive("Mate:8")= False
  Constraint.IsActive("Mate:12")= False
Else
  Component.IsActive("Module type A3:1")= True
  Component.IsActive("Module type A3:2")= True
  Constraint.IsActive("Mate:8")= True
  Constraint.IsActive("Mate:12")= True
EndIf
"Back wall
IfParameter("nA4")=0
  Component.IsActive("Module type A4:1")= False
  Constraint.IsActive("Mate:10")= False
Else
  Component.IsActive("Module type A4:1")= True
  Constraint.IsActive("Mate:10")= True
EndIf

```

Figure 13 The code in *InventoriLogic* to enable / disable modules for all MSR walls

5 CONCLUSIONS

As MSRs are produced at a customer's request who chooses the resistance grade and gives the available dimensions of the space in which to place such a product, the need for an MSR design exists for each new ordering. The new design demands time and risks the possible errors that can be costly if not detected in time. The biggest problems arise when assembling the product if appropriate number of modules have not been produced or an error in the dimensions of one of the component modules has been made.

Virtual 3D models that can be obtained by modern CAD software provide the ability to check the look of the strongroom on a computer and the interconnection of individual modules. Automation of the configuration process significantly reduces the time and thus reduces the design costs of the new MSR. The documentation obtained in this way is very accurate and without dimensional errors, which ensures that a high-quality product is achieved with

good production technology and good organization of production, and finishing and additional work that is currently present in the production of these modules to be eliminated.

The result of the automatic configuration of MSR, based on the platform proposed in this paper, is increased productivity, reduced production costs, shortened delivery time and improved product quality, thereby increasing the performance of the overall production system and its competitiveness on the market.

The practicality and validity of the proposed MSR configuration model has been tested and confirmed on a number of already implemented MSR examples, and the proposed platform can also be applied to the other manufactures of MSR.

Considering the complexity of the problem, the consideration in this paper is reduced only to the configuration of rectangular MRS. The developed platform requires further improvement and the future work should solve the following problems:

- configuring MSR with multiple doors,
- configuring MSR with sloped walls,
- configuring MSR with multiple rectangular shapes (stepwise),
- configuration of large-scale MSR with substructure,
- development of configurators for automatic configuration of MSR,
- parametric and variable module design with additional functions (ventilation, aeration and cable openings, etc.).

The new field of research, to which special attention will be paid, is the development and application of programmable WEB interfaces as a support for users to independently co-design products that meet their wishes and needs [3, 27].

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