

THE USE OF PARAMETRIC STRUCTURE MODELLING IN THE DESIGN PROCESS

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Abstract

Automation of processes related to design and manufacturing is one of the essential goals of most manufacturing companies. The use of modern computer-aided design systems CAD allows partial automation of such processes. The parametric model can be built in some CAD systems. In the parametric model, selected dimensions are treated as control parameters. By changing the values of these parameters, we can control the remaining geometrical dimensions of the model. These dimensions can be associated with linear control parameters using mathematical relationships. Parameterization allows you to associate a geometric model with a mathematical model and allows you to automatically make changes to all elements associated with the currently modified parameter. When working on a non-parameterized model, the changes in the modelled object must be applied separately for each part and subassembly of which it is composed. In a parametric model, changing one parameter entails changes in other parameters dependent on it. Parameterization of the model allows its use for further modification of the designed structure related to customer requirements, even for that very complex, as well as accelerating the design process itself. The article presents a three-dimensional geometric model of a boat davit created with the use of the Siemens NX 9.0 software. In the work, the geometry of the crane model was parameterized for the assumed values of its height and reach. As a result of parametric modelling, the values of the individual geometric dimensions of the device's structure elements and their mass were obtained. It was justified that thanks to the use of parameterized models, the time of design and construction processes can be significantly reduced, which makes the process more efficient.

Keywords: *parameterization, control parameters, modelling, davit, automation*

1. Introduction

Every design and engineering process in the ocean engineering industry is today supported by computers. This support includes the creation of three-dimensional models of elements. On the basis of models, detailed drawings of individual details are created, as well as assembly drawings. The three-dimensional model can be used to verify, visualize and simulate the operation of the future structure before it is created. This allows to eliminate any irregularities in the interaction of individual elements and to correct errors.

Parameterization of solid models consists in converting real dimensions into symbols. In the parametric model, dimensions are stored as variables. By changing the value of a variable, we control the dimensions of the model. Dimensions (variables) can be associated with mathematical relations. Changing the value of one variable will then change several dimensions of the solid. Parameterization is the introduction of variable features to the geometry of the element and it is most often used when the construction of the model is identical and the differences rely only on size dimensions [10]. Parameterization of geometric features of models is applicable where there is a need to introduce quick changes in geometry and the need to catalogue parts. It is possible to use parameterization in both the design process and cataloguing for all kinds of tools, such as: drills, taps, dies, milling cutters, turning knives, etc., where the geometry of individual details differs

only in the order of magnitude [9, 10]. Parameterization is also used to analyse spatial models to predict an equal type of scenario [4], and also in seismic tomography [6].

In this work, a davit boat has been parametrized. The crane radius and height from the deck of the crane (see Fig. 1) [1] were chosen as the main parameters.

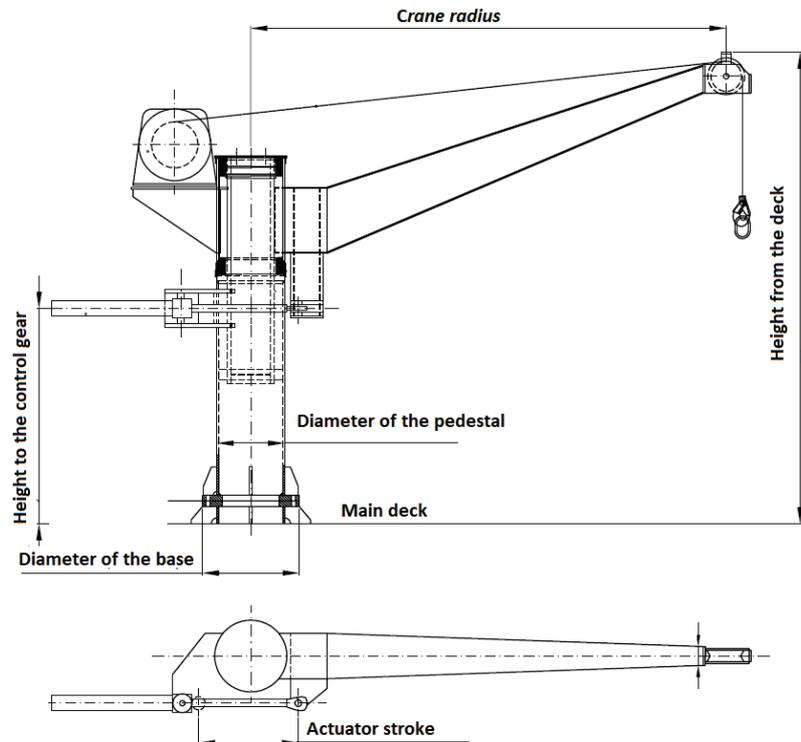


Fig. 1. Characteristic parameters of a boat davit

The purpose of the work is to show how the method of constructing a geometric model of a structure in a CAD system Siemens NX 9.0 affects the possibility of parameterization of a modelled structure. The boat davit model was given dependencies in the form of a function between two control parameters and the other specified parameters. The parameters that will change with the change of control parameters will be the values of geometrical dimensions of davit construction elements. After creating a geometric model, a complete list of individual elements of the structure was prepared with given mass values of these elements. The weight of davit construction elements and the mass of the entire modelled device was calculated using the functions of the Siemens NX 9.0 system.

2. Details of the parametrization of the model

Object modelling in CAD systems is possible thanks to the technique of give depth to cross-sections on a plane or by moving cross-sections along a path. In the Siemens NX 9.0 system, we can create solids based on a sketch created on a two-dimensional plane and rotate it around a designated axis. The geometric model created in the mentioned methods reflects the spatial structure of the object and the shape and size of its elements [2].

Geometric constraints are the relations between geometrical elements such as perpendicularity, parallelism, tangency, end connections and length equality (see Fig. 2) [7]. Correct defining of geometrical constraints in the sketch of the created model enables error-free parameterization. When changing the control parameters, the created model will then maintain the original shape; it will only change the proportions according to the parameterization of the dependencies [4].

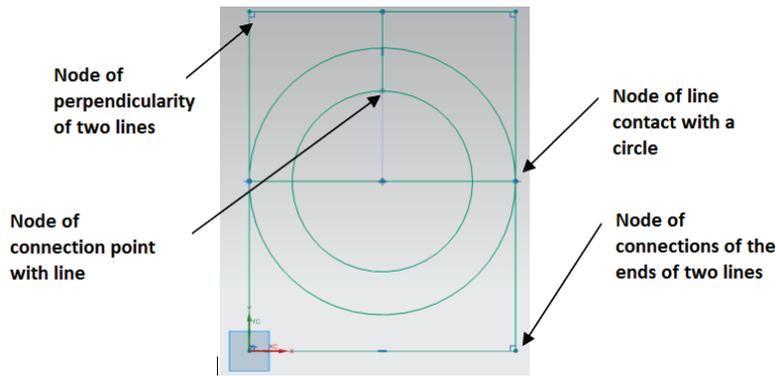


Fig. 2. An example of assigning geometric constraints (nodes) in the Siemens NX 9.0 program [7]

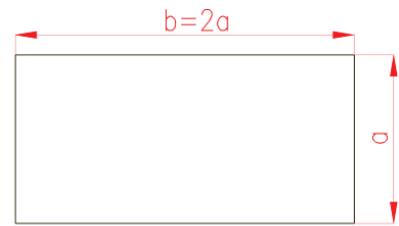


Fig. 3. Example of simple dimensional constraint [7]

Geometric constraints also include dimensional constraints. Dimensional constraints are defined by fixed numerical values or by functions defining relations between constraints. Geometric constraints also include dimensional constraints. Fig. 3 shows a simple example of dimensional parameterization. The dimension of the long side of the rectangle is bound in the form of a relationship (linear function) with the dimension of the shorter side.

The types of constraints [2] used in the Siemens NX 9.0 system were shown in the Fig. 4, they include:

- “Touch Align” – adjustment of two planes as aligned or tangent,
- “Concentric” – setting two circles concentrically,
- “Parallel” – setting two edges or two selected planes parallel to each other,
- “Perpendicular” – setting perpendicular to each other two edges or planes,
- “Infer Centre / Axis” – setting two elements coaxially.

Elements of davit equipment that were modelled but were not subject to parametrization in this work included rope winch, hydraulic cylinder and rope pulley. These elements could be selected according to the needs of producers’ offers.

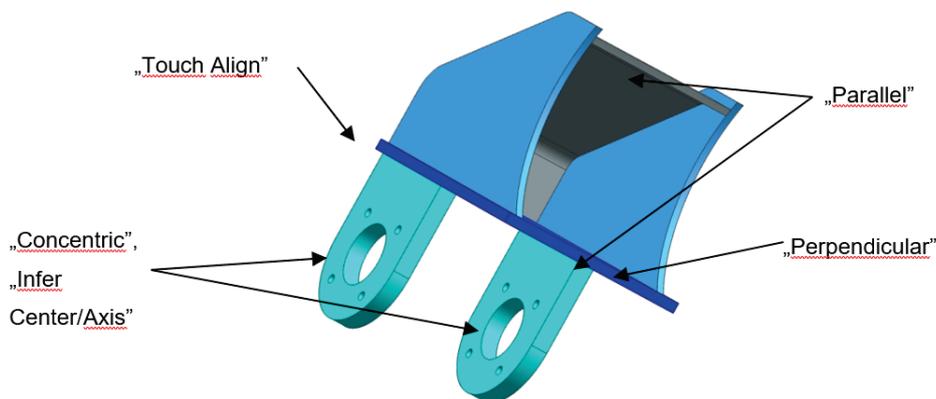


Fig. 4. Kinds of constrains in the Siemens NX 9.0 program [7]

For the purpose of developing the concept of a parametric crane model, two models of the object were made, building them according to different rules. The architecture of CAD system modelling used in the work is closely related to the way of building a spatial model. How the model is built affects the possibility of parameterization of the model as a whole as well as the possibility of parameterization of its individual elements.

The first of the davit boat models made model was built by connecting each other with the help of constraints of individual construction elements in the assembly, using the “Assembly” module of the Siemens NX 9.0 system. Each element of the crane’s structure was modelled in a separate

file based on a separate two-dimensional sketch, for example, the modelling of the davit column has been shown in Fig. 5.

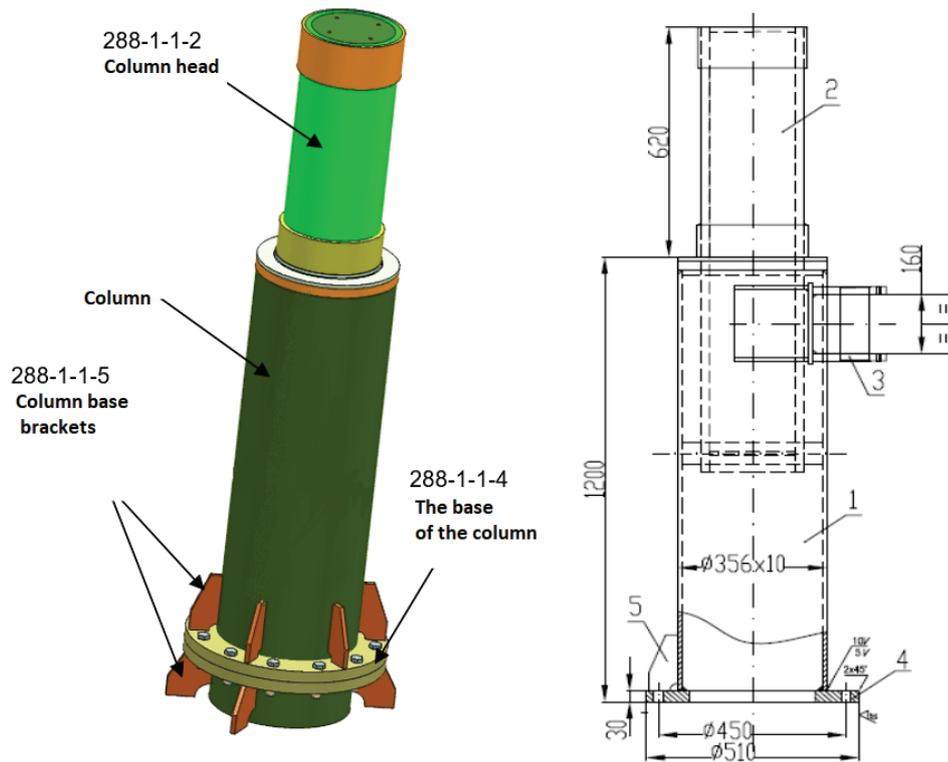


Fig. 5. Davit column with a head [7]

Then, in the “Assembly” module, all the elements of the model were sequentially attached to each other and connected with constraints. An example of a column assembly with a boom head is shown in Fig. 6.

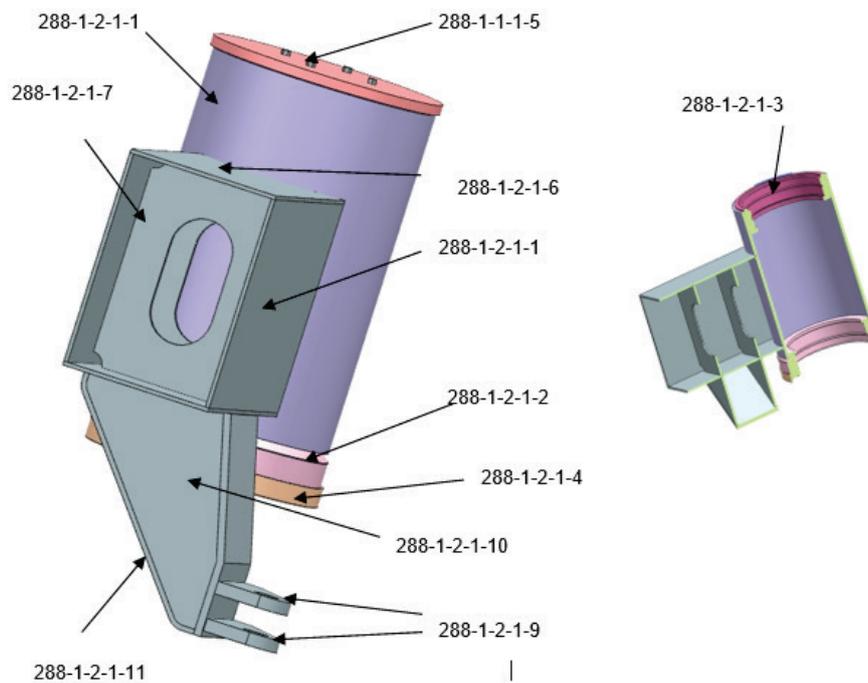


Fig. 6. Davit column head with boom head [7]

Ties were transmitted by determining how one element can move relative to the rest or to the entire structure. Ties determined the number of degrees of freedom for a given element. In building a model, the order in which constraints are created when creating part assemblies is important. This order significantly influences the possibility of successful parameterization of the created model.

After combining the elements of the model, it was not possible to parameterize it. The created model (see Fig. 7) after entering various values of control parameters did not change its form or only part of the structure was distorted. The decisive factor that caused the failure in parameterization was the discrepancy in the co-existence of the bonds that were given to each other. Some of the constraints formed, despite the fact that they were needed to connect the assembly, clashed with the rest of the structure.

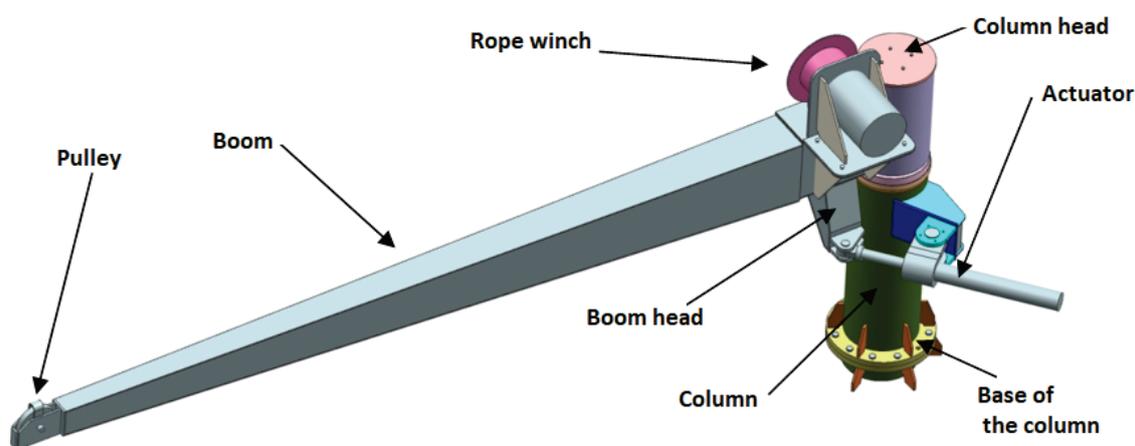


Fig. 7. Construction of the davit boat model [7]

The elements of the davit construction made in the first of the created models faithfully reflected the shape of the actual elements of the designed device. After entering into the system information about the material from which the model is built (in this case information about the specific gravity of the selected type), the system could generate mass values of all modelled parts. The masses of construction elements of the davit column are shown in Tab. 1.

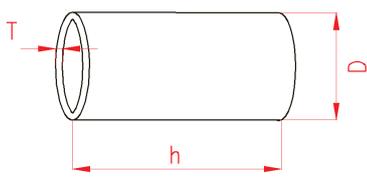
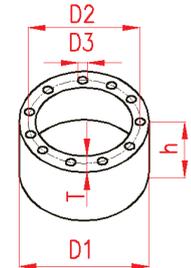
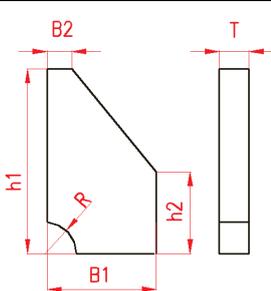
Tab. 1. Assembly list of davit column [7]

Assembly number	Element	Dimensions [mm]	Material	Quantity	Unit weight [kg]	Total weight [kg]
288-1-1 Column	Pipe	Φ356 x10 l=1165	Steel	1	99.13	99.13
288-1-1 Column	Plate	30x Φ356/300	St3S	1	19.08	19.08
288-1-1 Column	Plate	12x70x150	St3S	6	3.29	3.29
288-1-1-1 Column head	Rura	245x16 l=1225	R35	1	110.42	110.42
288-1-1-1 Column head	Plate	60x Φ335	St3S	1	19.08	19.08
288-1-1-1 Column head	Plate	40x Φ360	St3S	1	15.58	15.58
288-1-1-1 Column head	Plate	10x Φ212	St3SX	1	2.05	2.05
288-1-1-1 Column head	Plate	12x Φ212	St3SX	1	3.29	3.29
288-1-1-1 Column head	Plate	20x Φ360	1H18N9T	1	5.02	5.02
288-1-1-1 Column head	Plate	12x115x807	1H18N9T	2	6.10	6.10
288-1-1-1 Column head	Plate	12x82x807	1H18N9T	2	6.35	6.35

The second model of the davit was made in order to perform the correct parameterization after an unsuccessful attempt to parameterize the model made with the first method. This model was

created by creating a “base control“ sketch. The sketch included the main dimensions of the davit, which are also accepted control parameters – height and crane radius. All sequentially modelled parts were created on the basis of sketches, geometrically related to the base sketch. They were created directly from either the base sketch or sketches on planes created from the lines it contained. In order for the model to be a coherent whole, it was necessary to link the construction lines in the sketches with geometric constraints. The dimensions of each element were related to the main parameters. An example of building head sketching can be found in Tab. 2.

Tab. 2. Example of linking the main parameters to the dimensions of the model elements [7]

Assembling	Drawing of the element with marked dependent parameters, Coefficients of dependent parameters													
288-1-1 Column		<table border="1"> <thead> <tr> <th>h/H</th> <th>D/W</th> <th>T/W</th> </tr> </thead> <tbody> <tr> <td>0.570</td> <td>0.0894</td> <td>0.00227</td> </tr> </tbody> </table>	h/H	D/W	T/W	0.570	0.0894	0.00227						
h/H	D/W	T/W												
0.570	0.0894	0.00227												
288-1-1 Column		<table border="1"> <thead> <tr> <th>h/H</th> <th>D1/W</th> <th>D2/W</th> <th>D3/W</th> <th>T/W</th> </tr> </thead> <tbody> <tr> <td>0.0150</td> <td>0.128</td> <td>0.113</td> <td>0.00553</td> <td>0.00126</td> </tr> </tbody> </table>	h/H	D1/W	D2/W	D3/W	T/W	0.0150	0.128	0.113	0.00553	0.00126		
h/H	D1/W	D2/W	D3/W	T/W										
0.0150	0.128	0.113	0.00553	0.00126										
288-1-1 Column		<table border="1"> <thead> <tr> <th>h1/H</th> <th>h2/H</th> <th>B1/W</th> <th>B2/W</th> <th>R/W</th> <th>T/W</th> </tr> </thead> <tbody> <tr> <td>0.0377</td> <td>0.0126</td> <td>0.0178</td> <td>0.00754</td> <td>0.00503</td> <td>0.00126</td> </tr> </tbody> </table>	h1/H	h2/H	B1/W	B2/W	R/W	T/W	0.0377	0.0126	0.0178	0.00754	0.00503	0.00126
h1/H	h2/H	B1/W	B2/W	R/W	T/W									
0.0377	0.0126	0.0178	0.00754	0.00503	0.00126									

After building the model with this method, the object correctly changed the dimensions and shape after entering various values of the control parameters. It was possible to read the dimension values of the part elements for different values of the height and reach of the modelled structure. The example results of the parameterization carried out on the second of the created models are presented in Tab. 3. The dimensions of davit construction elements were read after the simulation in the NX program for different values of the assumed control parameters.

3. Summary

In one of the cases considered, the parameterization of the model failed. The reason was the inconsistency of the constraints defining the number of degrees of freedom of a given element in the submission of the object. These ties were given when combining elements of the model. The model created in this way – by connecting together in the “Assembly” module of the Siemens NX 9.0 system, the structure elements into one whole can be parameterized, however it is a process requiring a higher level of knowledge of the NX 9.0 system operation. The process of parametrisation on such a built model takes much longer than parameterizing the model made with the other method presented.

Tab. 3. Dimensions of davit construction elements after parameterization [7]

No of the assembling	Dimensions [mm] after parameterization for H = 2200 mm and W = 4200 mm													
	h	h1	h2	h3	B1	B2	B3	D	D1	D2	D3	D4	R	T
288-1-1 Column	1254							376						11
	33								538	475	23			5
		158	53		75	32							21	13
288-1-1-1 Column head	1342							259						17
	66							354						47
	44							380						60
	11							224						59
	13							224						
	22							380						60
	121							276						11
	94							284						13
288-1-2-1 Boom head	601							376						11
		47	21	13					384	306	290	354		
		16	78	12					354	290	306	323		
	44							393						4
	381				6	279								
	7				241	279								
	288-1-2-1 Boom head	372		106		6	241							53
376		127			179									13
22					63	179							42	
		127	53		53	154								8
		8	53		53	8								179
288-1-2 Boom	7				253	4246	106							
	7	357	146		4247	4200								
	7				253	4221	106							
	165				106	11								
	165				243	11	53							
	110				42	11								
	44				53								22	6

Parameterization of the model created by the second method of building geometry of a spatial object presented in the work in the CAD system was successful. The aim of the work was achieved by creating a model consisting of assemblies coming within the model based on sketches associated with the so-called “base, controlling” sketch. This sketch contained dimensions that were the basis for determining the remaining dimensions. The dependencies between the control dimensions and the dimensions associated with them were determined in the form of linear functions. This method of building the model allowed creating a simulation of geometric dimensions of the davit construction for a few adopted values of control parameters. The use of the CAD computer system to create a crane model enabled its parameterization, thanks to which it was possible to obtain information on the geometry details after setting the control parameter values by the ship-owner. It was possible to quickly present the appearance of the crane and data on the masses and dimensions of its components during the several operations performed in the system used.

The model made presents the visualization of the real structure; it allows you to view the interior and equipment of the designed device without having to review the construction drawings. The davit model created is technically useful due to the possibility of creating documentation for solutions dependent on the ship-owner, for the chosen construction, in a simpler and shorter way than the traditional way of the design loop.

When constructing a geometric model of a structure in a CAD system, one should pay attention to the method of creating a model in the case when we want to subject the modelled object to subsequent parameterization. The method of building the model affects the performance of parameterization and the possibility of subjecting the model to further research (strength, design optimization, selection of materials, 2D and 3D drawings generation and development of manufacturing technology, export to exchange files in a different format and use in the ship's model).

Each of the available CAD systems differs in the way of defining geometry and giving parametric features to models, this fact should be taken into account when choosing a system.

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