Development of integrated intelligent CAD system for calculation, designing and development of bridge crane

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During process of product development and design, it is important to keep production cost as small as possible. One way to reduce the production cost is by degrading the quality of the product, which is "worst-case" scenario and it should not be used. Another way is to turn to the application of new knowledge and insights, which enables better utilization of resources and processes. New knowledge may include new materials and/or new technologies, but may also include new ways and methods of product development and design. The increasing complexity of products, the use of new materials, methodologies and technologies, require increasing computer support for the design process. Because of this, there is a need for a better scientific approach and a better understanding of the design process using a number of software design tools, interaction between these tools and better collaboration between designers. This paper describes the process of developing the knowledge based intelligent integrated computer aided design (IICAD) system for the calculation, dimensioning and development of a bridge crane model with two main supports. This methodology of IICAD software development can be used to develop numerous other IICAD computer systems for various fields of engineering. Main contribution of this paper is above mentioned and presented methodology. Also, goal of this paper is to prove that standard computer aided design (CAD) systems, needs to be expanded with this knowledge based intelligent integrated systems to achieve higher levels of performance.

Keywords: integrated intelligent CAD system; design; calculation; bridge crane; main girder

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1. Introduction

The process of product design, during product development, is performed in accordance with market demands, technical, functional, economic, ergonomic, aesthetic and environmental requirements [1]. It is a very complex process that involves many procedures and requires the teamwork of designers and engineers of different profiles [2]. To support designers, it is necessary to develop environments for integrated intelligent systems that provide information for rapid and intelligent decision making throughout the entire design process [3]. So far, various methodologies and systems for intelligent design have been developed. Most of them, in the process of product design, apply individual artificial intelligent (AI) techniques [4], such as: Knowledge Based System (KBS) [5], Artificial Neural Networks Systems (ANNS), Genetics Algorithms (GA) and Case-Based Reasoning System (CBRS). These systems are often called Integrated Intelligent Computer Aided Design (IICAD) systems and they are most commonly developed for a specific product or family of similar products. There are many examples of systems already developed by other authors [[6–8] and these authors [9–12]. Standard computer aided design (CAD) systems, which are already available on the market and are already implemented in a lot of companies in their product development and design processes, needs to be expanded with this knowledge based intelligent integrated systems to achieve higher levels of performance. A bridge crane with two main girders, consisting of a bridge A and a carts winch B (Fig. 1). The bridge is a steel structure made up of two main carriers, which are placed along the rail (a). The rail is used to guide the wheels (b) from the driving winches. The ends of the main carriers are fixed (welded) to the transverse carriers (c). Transverse carriers are connected using the wheels to the bridge (d). These wheels are moving on the rails placed on carriers of the crane trails (s). The drive of the bridge is achieved by direct connection of the engine and gearbox (f) with the drive wheels (g). Control of all crane movements is done by steering (h), electric installations are located on a girder (i).

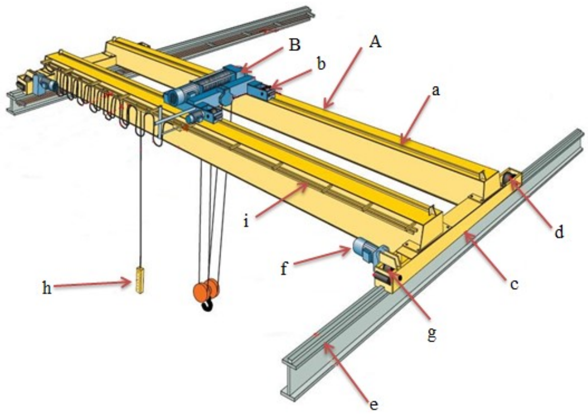


Fig. 1. Double girder bridge crane.

2. IICADmd system

Development of the knowledge based integrated intelligent CAD system for calculation, designing and development of bridge crane 3D model (IICADmd) went through several stages:
I problem identification and goal setting,
II mathematical modeling of bridge crane,
III parametrization and development of 3D geometric model of bridge crane,
IV design of the system,
V program implementation (coding),
VI testing.

2.1. Problem identification and goal setting

Calculation and design of bridge cranes is a long process, it takes a lot of time from engineers. To facilitate the process, the idea is to develop an interactive knowledge based integrated intelligent system that will enable quick calculation of the main elements of the bridge crane, the automatic development of a 3D geometric parametric model and numerical stress deformation analysis of the main girder of the bridge crane. Standard commercial engineering software's are developed for wide range of use. They are not specialized for specific engineering application like bridge crane design. Because of that, if someone want to design a bridge crane using some of commercial software's he needs to calculate everything by hand and then use commercial software to design a bridge crane. Also, standard commercial software's do not have all standard elements which are used to design a bridge crane. Designer needs to design them manually. All this above-mentioned problems, are solved by development of the knowledge based integrated intelligent CAD system for calculation, designing and development of bridge crane (IICADmd). IICADmd system have all calculation, design and analysis in one software developed for specific engineering application. The architecture of the IICADmd system is shown in Fig. 2.

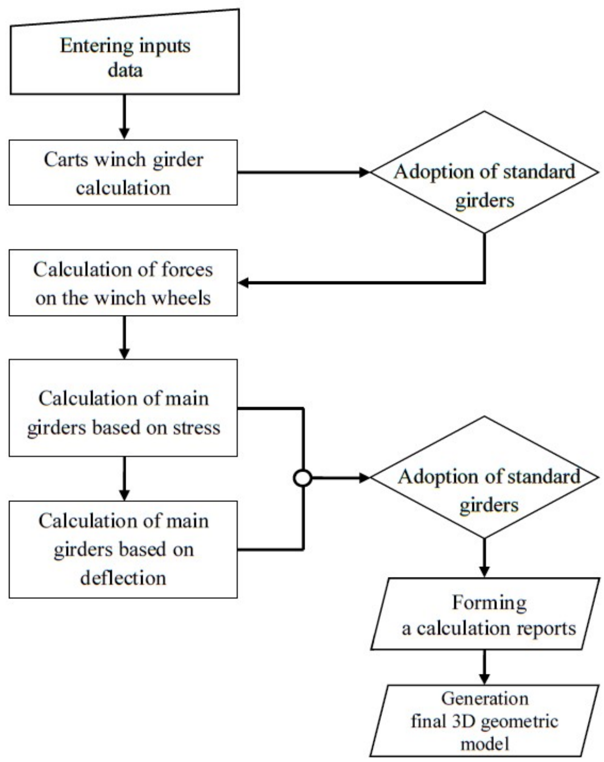


Fig. 2. Architecture of the IICADmd system.

2.2. Design of the IICADmd system

The IICADmd system was designed through two forms, the initial form and the main form (Fig. 3). The initial form contains only a button that starts or closes the program. The main form consists of several parts. At the top of the form is the File bar, which is used to open or save the currently calculated inputs. The system, in its main form, contains of six tabs that guide user through the analytical calculation from data entry to results. After entering the input data, user need to click the CALCULATE button. After calculating the main girders of the crane bridge, as well as the design of the winch carriages, the software automatically selects the standard IPE profile for the construction of the crane bridge, as well as the standard pipes for making the winch carriage. After the calculation, the system enables user to automatically generate 3D parametric model of the bridge crane by clicking the START CATIA button.

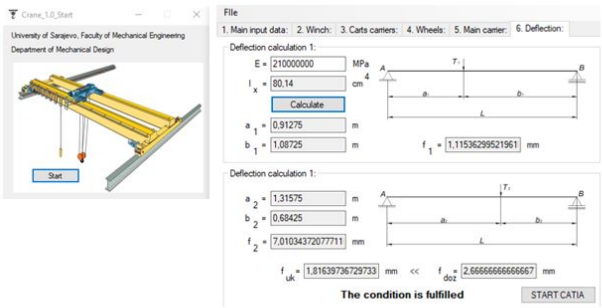


Fig. 3. Initial (left) and main form (right) of IICADmd system.

2.3. Program implementation (coding)

The design and writing of IICADmd's programming code was done in C# programming language in Microsoft's Visual Studio programming environment. Code of the IICADmd system is to complex and too wide to be presented here.

3. The mathematical model of the bridge crane

The calculation of the bridge crane design shown in Figure 1 consists of the calculation of the carts winch girders, the calculation of the forces on the carts wheels and the calculation of the main girders [13, 14]. This calculation is integrated into the developed IICADmd system. In order to check the main girders of the bridge cranes, the first step is to determine the forces acting on them. These forces depend on the load distribution on the winch carts or on the wheels of the carts. The calculation is carried out according to the procedure outlined below, taking into account the following information: Q (N) – load capacity of the bridge crane, L (m) – length of bridge, Ln (m) – range of main girders. The carts winch will be designed based on the winch dimensions and the range of the main girder of bridge crane. With the known dimensions of the winch, the range of the main supports will be chosen constructively due to space constraint. Fig. 4 shows the winch carts, with the locations of the reactions. The dimensions on the winch carriages depend on the load capacity of the bridge crane and

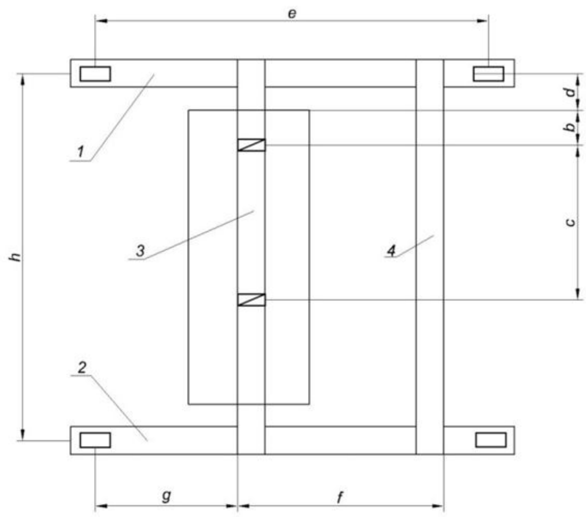


Fig. 4. Carts winch (1,2 - lateral catrs supports; 3,4 – main girders of carts winch).

the overall dimensions of the winch itself. In addition, it is necessary to dimension the cross-section of the pipes used to design the carts winch girder. The square cross-section tubes were used in the calculation. The cross-sectional size calculation is reduced to a statically determined problem, where the more loaded side of the carts winch girder is viewed as a beam with two supports, Fig. 5. The solution

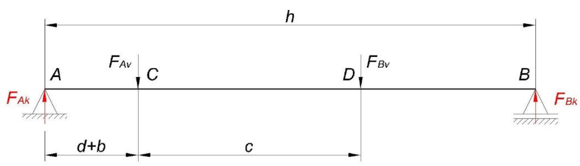


Fig. 5. Girder of carts winch.

of the beam gives the value of the reactions of the supports, and therefore of the bending moments in characteristic places. The cross-sectional dimensions of the winch girder are calculated by the expression:

$$\sigma_s = \frac{M_{smax}}{W_x} \leq \sigma_{doz} \qquad (1)$$

Where: σ_s (MPa) - bending stress, M_{smax} (Nm) - maximum bending moment, W_x (cm3) - resistant moment of inertia σ_s (MPa) - allowed stress for the selected material (160 MPa). From equation (1) user can calculate value for resistant moment of inertia, and based on these values choose a square tube dimensions. After dimensioning trolley winches, by Andrea method, calculation of pressures on the wheels for a specific trolley, which is shown in Fig. 4, is carried out. Areas calculated:

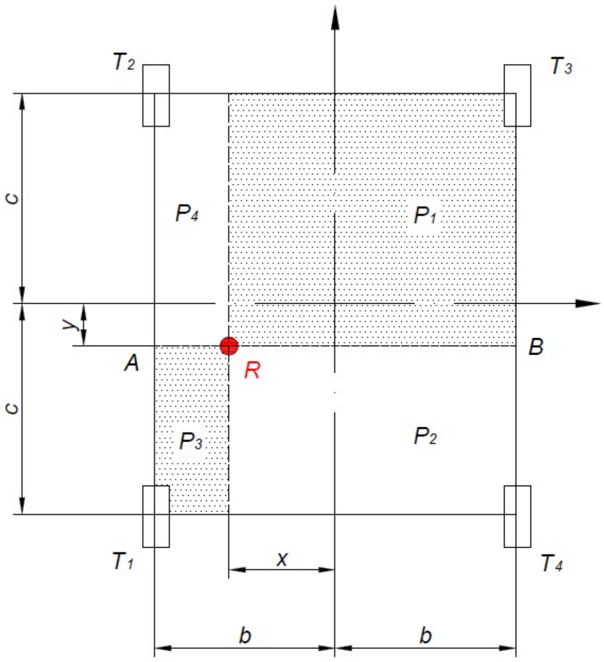


Fig. 6. Carts winch with dimensions and resultant force.

$$\begin{aligned} p_1 &= (b+x)(c+y) \\ p_2 &= (b+x)(c-y) \\ p_3 &= (b-x)(c-y) \\ p_4 &= (b-x)(c+y) \end{aligned} \tag{2}$$

Forces on the wheels:

$$T_i = \frac{R}{4bc} P_i, i = 1,2,3,4 \tag{3}$$

After calculations of the forces on the wheels of the carts winch, dimensioning of the main bridge girder can be started. The profile is calculated for more loaded girder. Due to the design of the winch, one girder is always more loaded in comparison to another. In particular, I - profiles were selected.

In order to choose the profiles, the first step is to calculate the axial resistance moment of inertia of Wx, according to Fig. 7 based on expression (1). Using expression (1), in addition to known values of maximum bending moment and allowed stress of the girder material, an axial resistance moment of inertia can be obtained, by which, using tables for standard I-profiles, a profile with equal or first higher value of axial resistance moment of inertia is selected.

4. Parametrization and generation of a 3D geometric model of the bridge crane

For the purpose of the forthcoming research, the model of the bridge crane currently used in the Laboratory (LabTD) of the Faculty of Mechanical Engineering in Sarajevo is

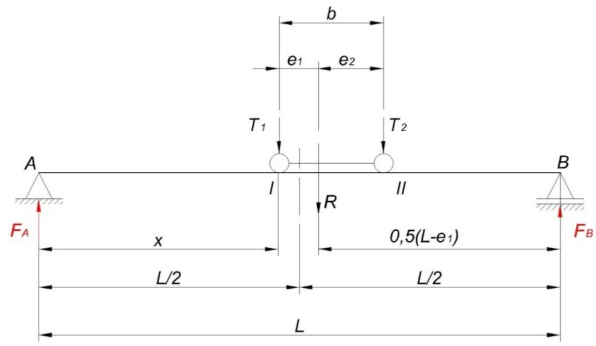


Fig. 7. Main girder of the bridge crane.

presented. The generated 3D model is fully parameterized allowing automatic modification of all dimensions of the bridge and the carts winch. Thus, the model can be applied to any crane load capacity, bridge length or main carrier range. The biggest advantage of this type of modelling is reflected in the possibility of a rapid change in size, shape and position of the modelled elements. Fig. 8 shows the design model of a laboratory bridge crane, on the basis of which a 3D geometric model was developed. The model is parameterized to realize the integration of an intelligent CAD system from calculation to the generation of the final 3D geometric model. This kind of automated calculation and geometric modeling can accelerate the design process of bridge cranes. Since the bridge crane is assembly of

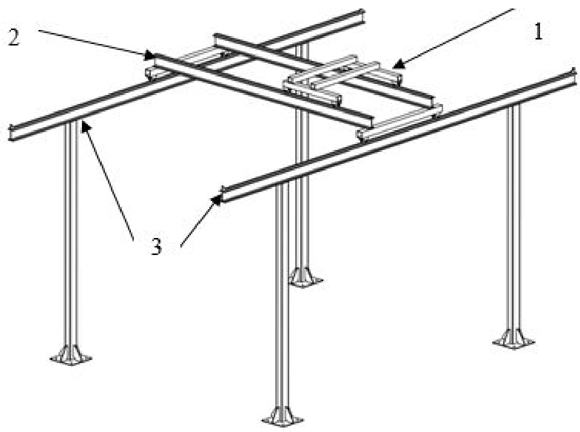


Fig. 8. Design model of the bridge crane (1 – carts winch, 2 – bridge, 3 – girders of the bridge).

multiple parts, it was necessary to model each of the parts separately and to parameterize them. When assembling parts (Assembly Design) formulas and certain dependencies between individual parts were used, which provided automatic modification of the complete model of the bridge crane according to the data obtained from the calculation. The first step is to model the I-profile by drawing an initial

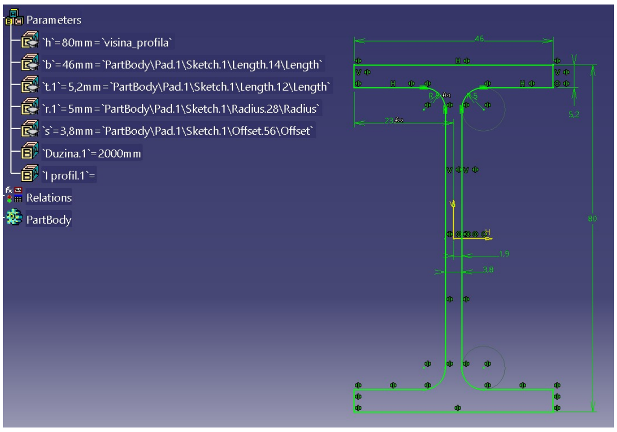


Fig. 9. I – profile Sketch.

Sketch (Fig. 9) to which a third dimension is added using the Pad command (Fig. 11). When drawing Sketch, it is necessary to make sure that the profile dimensions are aligned with the standard. In Sketch, a complete parameterization of the dimensions was performed, and a dependency between the dimensions was established. When parameterizing the I-profile, the following parameters were created: profile height, profile width and profile wall thickness. The parameterization process starts by running the Formula command within the CATIA software, after which the window shown in Fig. 10 opens. This window is used to create the parameters and to associate them using certain formulas and dependencies. After the Sketch is completed, the Pad command is used (Figure 11). In order to develop fully integrated IICADmd system, a table was created in Excel with all standard I-profiles and their measures, which is linked to the CATIA software using the Table command (Fig. 12). After the previous step, an option appears in the Part tree with the option to select the appropriate standard I-profile established by the calculation (Fig. 13). The next step is the installation of the bridge crane bridge in the Assembly Design module, where the distance between the I-profiles is also parameterized, which can be changed according to requirements. The bridge girders along with the wheels were also chosen. The sub-assembly of the bridge is shown in Fig. 14.

In the same way, a model of winch cart was created using standard square cross-section tubes. In the first step, the pipe is modeled according to standard dimensions in the same way as for the I-profile. Then the Excel table is

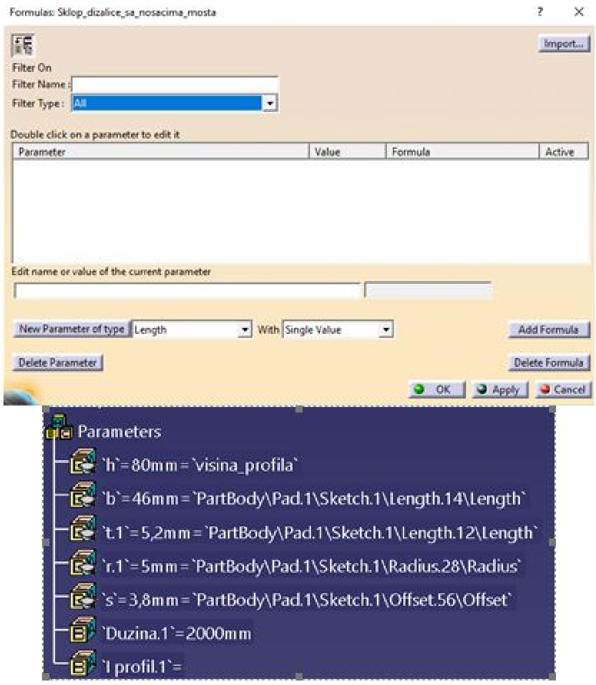


Fig. 10. Parametrization of I - profile.

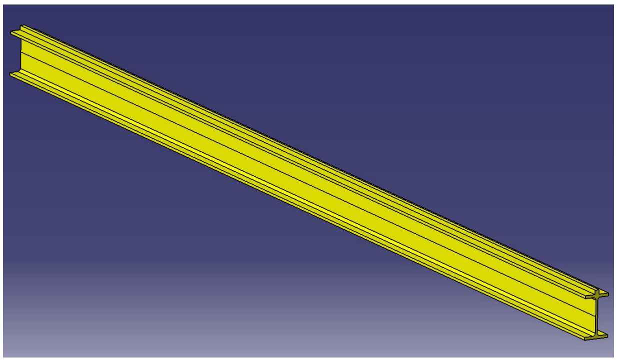


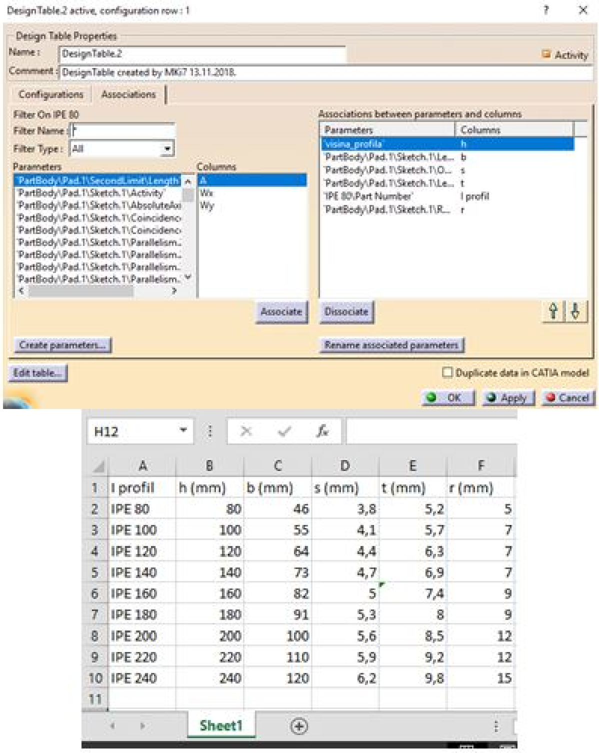
Fig. 11. Comand Pad.

made with a standard pipe dimensions. The Table option in CATIA software is used to establish a connection between tables and models. After the pipe modeling process was completed, it was necessary, using the Assembly Design module, to create a sub-assembly of winch carts, which was also fully parameterized to be used in the IICADmd system environment (Fig. 15).

Finally, Fig. 16 shows the final 3D geometric fully parametrized model of the bridge crane.

5. Conclusion

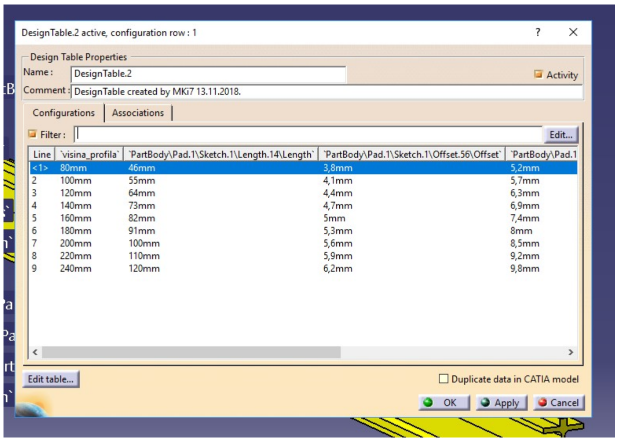
The method of how to create and develop integrated intelligent, knowledge based, CAD software is shown on practical example of IICADmd system. The system is de-



	A	B	C	D	E	F
1	I profil	h (mm)	b (mm)	s (mm)	t (mm)	r (mm)
2	IPE 80	80	46	3,8	5,2	5
3	IPE 100	100	55	4,1	5,7	7
4	IPE 120	120	64	4,4	6,3	7
5	IPE 140	140	73	4,7	6,9	7
6	IPE 160	160	82	5	7,4	9
7	IPE 180	180	91	5,3	8	9
8	IPE 200	200	100	5,6	8,5	12
9	IPE 220	220	110	5,9	9,2	12
10	IPE 240	240	120	6,2	9,8	15
11						

Fig. 12. Connection table in Excel with CATIA software.

veloped with a goal to enable engineers and researchers to automatically calculate dimensions of all components of bridge crane and to generate the final 3D geometric model. Thus, the developed system enables more efficient and faster work of engineers when designing bridge cranes. This methodology can be used for development of any type of integrated intelligent, knowledge based, CAD system for different types of engineering design. Further development of the IICADmd system can go in several directions, such as: checking the stress status, optimizing the construction of bridge cranes, automatic generation of technical documentation, etc.



Line	'visina_profila'	'PartBody\Pad.1\Sketch.1\Length.14\Length'	'PartBody\Pad.1\Sketch.1\Offset.56\Offset'	'PartBody\Pad.1
<1>	80mm	46mm	3,8mm	5,2mm
2	100mm	55mm	4,1mm	5,7mm
3	120mm	64mm	4,4mm	6,3mm
4	140mm	73mm	4,7mm	6,9mm
5	160mm	82mm	5mm	7,4mm
6	180mm	91mm	5,3mm	8mm
7	200mm	100mm	5,6mm	8,5mm
8	220mm	110mm	5,9mm	9,2mm
9	240mm	120mm	6,2mm	9,8mm

Fig. 13. Selection of standard I profile.

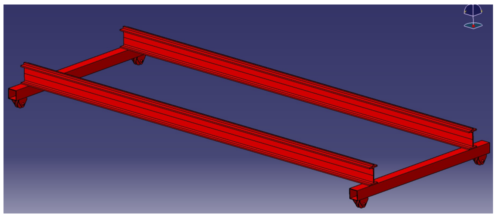


Fig. 14. The subassembly bridge of the bridge crane.

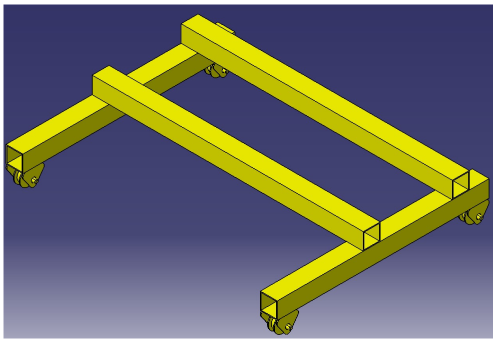


Fig. 15. Carts winch subassembly.

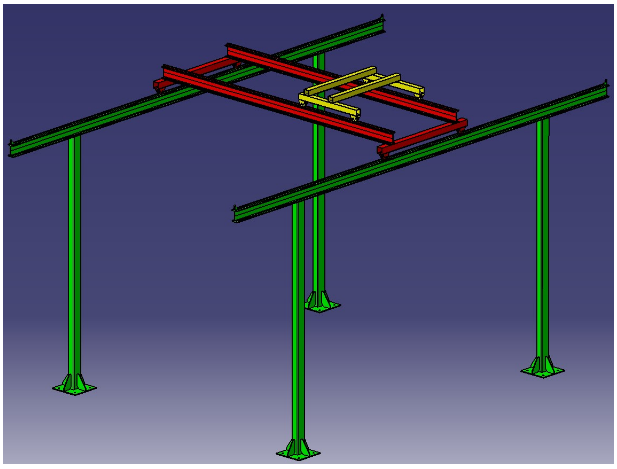


Fig. 16. Final 3D geometric model of a bridge crane.

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