Top down designing spacecraft in CAD applying knowledge-based parametric patterns

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Abstract. The article demonstrates that creating theoretically grounded data model and product development processes within a common information space of the enterprise using the top down design approach is the assignment to be performed if the researchers take into account a wide variety of the interrelated issues, such as: managing the changes and configuration, reusing data, realizing the advantages of knowledge-based patterns. The similar data models and processes are currently demanded, since their implementation significantly reduces the time and money expenditures and improves the product quality at its development stage. The authors present their methodology of top down designing spacecraft based on top level CAD using knowledge-based patterns of spacecraft structure elements.

1. Introduction
Efficiency in using life cycle information support technology is a crucial factor providing high rate and product development quality [1]. The information support of product life cycle is realized in the common information space (CIS). Technically, CIS is built with complementary manufacturing CAD of different purposes. CIS core is the product data management system (PDM) relevant to a customization of industrial database management system (DBMS). Kovalev I.V. et al. [2] highlights that currently a common approach does not present to form PDM data structure and their transformation process (data models and processes). An attempt to construct a model based on unified system of engineering drawings (USED) reduces the system efficiency.

CALS methodology, solving the problem of data and process modeling, has become outdated and it does not realize the advantages of the current CAD. Therefore, the present-day situation highlights the significance to create a methodological ground to develop data and process structures of CIS permitting to use the capabilities of the current CAD.

Performed within the developed technological platform together with the universities and aerospace enterprises in Russian Federation [3], the research proved applying top down designing to be one of the advanced approaches to design the data and process modeling of CIS. The main classification feature of the top down designing method is the availability of the control links among the objects of data structure of CIS. Solving the assignment of CIS development using the top down designing method is considerably sophisticated due to the necessity in the integrated life-cycle analysis approach, presented by various CAD(s) within CIS.

The research [4] specifies the data and process modeling of CIS, developed with top down designing method, obtains the following advantages:
- the possibility to manage the changes in a product efficiently at all PLC stages following their status;
- the possibility of encapsulation into information structures of the control logic (CAD intellectualization technology);
- the possibility to reuse data efficiently, based on applying the knowledge-base parameterized patterns (KBPP);
- the possibility to organize profound new processes in product development, relied on the multi-field parameterized product model (MFPPM) and envisaging changes in real time (continuous engineering).

Applied to the electronic model of a product (EPM), top down methods are based on CAD parameterization technology. Academic V.N. Chetvertukhin is the founder of the parametric method [5].

Data and process polystructure model for the top down designing were based on the data and process V-model was developed in both Germany and the USA in 1980-s. In 1996 Usakov V.I. proposed the designing polystructure technology (on the example of spacecraft actuator mechanisms) [4].

Employing the polystructure model features, the data and process model of CIS is targeted on data management of EPM and it is not designed to describe the multi-field data. The model does not consider the requirements of data reuse and intellectualisation possibilities.

2. The problem statement of designing knowledge-based parametric patterns

Applying knowledge based engineering in CAD is a CAD approach increasing considerable efficiency of a designer and the quality of a product.

Knowledge based engineering allows to encapsulate physical parameters, connected with geometrical as well as knowledge base elements, such as formulae, rules, tests and reactions into three dimensional engineering models [6]. Parametric knowledge base models designed with KBE technology can be programmed to respond to the changes of the geometric and other input parameters [7].

A different possibility to apply KBE technology is to design knowledge base parametric patterns (KBPP) of assembly components, parts and structure members [8]. KBPP can be used to develop typed elements of a product structure. Using KBE considerably increases both designer performance efficiency and the quality, and the product technological effectiveness due to using tested designs.

KBPP can be used only to develop products by top down approach. Therefore, applying KBPP requires consideration of the methodology of top down designing a product.

KBPP can be applied to develop products of high degree standardization of the design. To develop a methodology to top down design using KBPP for every product type, it is required to specify a product structure due to dividing into patterns.

3. Method of solution

The authors have developed and implemented the top down designing methodology for spacecraft using KBPP. KBPP libraries are applied at the design and engineering stages of spacecraft; it significantly accelerates the development process and allows to study a greater number of design variants within the required time limits, and to decrease the number of routine tasks. The final spacecraft model obtains complete parameterization to make changes in the design and engineering electronic product modeling.

The spacecraft design process consists of two succeeding stages [9]: designing and engineering. The resulting data entities for the stages are designing and engineering electronic product modeling (EPM). Top down designing methodology has to anticipate a parameter connection between a designing and engineering EPM to manage changes in the project. The designing and engineering EPM require various degree of specification. On the assumption of the listed requirements, a three-stage parameterization scheme has been chosen to develop a master model (skeleton) of the designing and engineering EPM.
The master model presents a CAD part and it is developed with knowledge base pattern library of design elements (fig. 1). The master model contains the main product dimensions (nose cone contour, a composite grid structure model, antenna and sensor radiation zones and others).

![Figure 1. Spacecraft master model.](image)

The designing EPM is parametrically linked to the master model; it is developed with full-scale mock-up libraries of spacecraft engineering elements, equipment location zones, designing mock-ups of spacecraft devices and assemblies. The designing EPM allows to obtain a spacecraft theoretical drawing. Figure 2 presents parameter link structure at EPM.

![Assembling Skeleton](image)

- Assembling Skeleton
- Functional Chart
- Assembling Skeleton 2 in context
- Assembling Skeleton 1 in context

![EPM Assembling](image)

- EM assembling of unit 1
- EM assembling of unit 2
- EM assembling of unit 3

![Assembling 1](image)

- Assembling Skeleton 1 out context
- Part
- Interface skeleton 1-2 in context

![Figure 2. Parameter link structure in EPM.](image)
The designing EPM is also parametrically connected with the spacecraft master model, however, it is created with a different set of libraries containing elements of higher degree specification. The designing EPM provides the design documentation for spacecraft.

The key issue to create libraries of knowledge base parametric mock-ups is the spacecraft structure decomposition to hierarchical components to form spacecraft models with minimal efforts.

Formalizing such sophisticated as spacecraft completely is almost impossible; therefore, developing libraries of knowledge base elements specify a goal to automate the routing work of a designer and a projecting engineer. According to the professional evaluation, the efforts to develop a spacecraft in the design departments decreases approximately up to 50% after the methodology has been implemented. Further development of the methodology assumes to connect the processes of spacecraft structural design and its spatial arrangement (master-model creation) within an integrated information pattern using RFLP data model.

Developed and presented at Fig.2, the parameter link structure in EPM obtains a versatility characteristic providing a schematic synthesis of a product parameterization, meeting the requirement to manage changes together with team effort in the EPM environment. It should be highlighted the approach can be applied to different machine-building spheres.

The product parameterization pattern is realized on the basis of the Large Assembly Concurrent Design (LACD) methodology, PDM – ENOVIA Smarteam system. The pattern is specified while realizing the top down designing methodology for a manufacture information system [10], where the methodology is presented to design an extra large spacecraft EPM with top down designing and the adjacent models.

4. Conclusion

The article presents a methodology to design a structure of EPM parameter links, developed by the authors, for the sophisticated machine-building products; the methodology allows to design parameterization patterns taking into account the total requirements to manage changes, team effort in the EPM environment and data reuse.

The methodology obtains a versatility characteristic and it is applied to different machine-building spheres. It should be noted that meeting the requirements of top down designing and data reuse allow to eliminate restrictions to EPM size. While designing spacecraft, the given approach, based on designing multi-level EPM with knowledge base parameterized patterns, is able to reduce the duration of designing some components of spacecraft structure significantly.

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