A generalization of approaches to creating a digital passport supporting the stages of the electronic product life cycle and the features of the formation of design decisions based on it

Donetskaya Julia, Gatchin Yuriy
(ITMO University, St. Petersburg, Russia)
e-mail: donetskaya_julia@mail.ru

Abstract: *The paper substantiates the need to generalize approaches to creating a digital passport supporting the stages of the life cycle of an electronic product. For this, the results of the analysis of design and production procedures and product data at the stages of the life cycle are presented, on the basis of which the components of a digital passport are formulated as pairs of values "information object - design and production procedure". Information objects are determined by PDM, ERP, MES, QMS systems and electronic document management systems. The list of design and production procedures is determined by the automated processes of a particular enterprise, which determines the variability of the digital passport. Also, the work substantiates the need for the formation of design decisions and the features of the formation of design decisions based on them are shown. The formation of design decisions is associated with the corresponding tasks formulated in the form of linguistic variables, which allowed to develop the generation of design solutions, according to which their desired version contains the associated components of a digital passport that fall inside the area specified by the values of the linguistic variable. The results obtained can be used in order to create signatures and semantics of applied unified services for a digital passport in the instrument-making industry, used in the development, delivery and maintenance of electronic products.*

KEYWORDS: *DIGITAL PASSPORT, SELECTION OF COMPONENTS OF A DIGITAL PASSPORT, TASKS OF DESIGN DECISIONS FORMATION.*

1. Introduction

A modern electronic product is a complex hardware-software complex, the creation of which is peformed on the basis of a customer's application. The application determines the lists and terms of the work, as well as their executors, both from the number of divisions of the instrument-making enterprise and organizations, which sets the task of operational interaction between them - the exchange of relevant data on the product. The solution to this problem is provided by the operation of a variety of PDM, ERP, MES and / or QMS systems [1-4], including electronic document management systems (EDMS), which creates each enterprise's own integrated environment.

This increases the efficiency of interaction between divisions of one enterprise [5], but not interaction between enterprises. In most cases, it is implemented in the traditional way - correspondence by e-mail and the exchange of technical documentation on paper. At the same time, new methods are gaining popularity, which consist in introducing the same systems with synchronization of versions and models of stored data by all participants in the interaction [6-10] or in using a neutral data exchange format in the STEP language, which also requires prior coordination. The obvious disadvantages are as follows:

1) simultaneous support of several versions of the same software for interaction with various enterprises;
2) coordination of models and formats of data exchange between all participants of electronic interaction when concluding contracts;
3) coordination of the types of systems being introduced since it is impossible to transfer data about the product and the design and production procedure if the system is not implemented at the enterprise or information storage is not provided;
4) own interpretation of the contents of a file of a neutral data exchange format by each enterprise, which creates difficulties when reading it in other organizations.

The disadvantages are even more significant if we take into account the development vector of Industry 4.0 [11-15] - minimization, up to the complete exclusion, of the influence of the human factor on production processes. For the instrument-making industry, this means the selection, collection and analysis of product data and design-production procedures, which corresponds to the creation of a digital passport supporting the stages of the life cycle of an electronic product [16, 17] for making design decisions.

Thus, it is advisable to solve the following problem - a generalization of approaches to creating a digital passport and formulating the features of the formation of design solutions based on it at the stages of the life cycle in the instrument-making industry, which this article focuses on.

2. Procedures and data analysis on the electronic product at the stages of the life cycle

According to the research results, the content of the digital passport is determined by the types of data on the electronic product that are generated and modified in accordance with the design and production procedures at the stages of the life cycle.

Therefore, at the stage of concluding a contract, the company's employees consider applications received from customers, based on which they prepare materials for concluding contracts.

If an application for development is received, then with its agreement upon and approval, lists of the developed and supplied component parts of the product are formed, indicating the contractors in the form of divisions of the enterprise and organizations. If an application for the supply of products is received, then lists of the developed and / or corrected design and program documentation are formed, indicating the contractors in the form of enterprise units, as well as lists of supplied components and relevant organizations [18].

The data obtained in this case are the initial information in the form of lists and deadlines for the execution of work stages when drawing up contracts for the development or delivery of products, including contracts with co-contractors.

The development stage is to create sets of new or revised design data on the product in the form of an electronic product structure in a PDM system (ESI-PDM) containing 3D models, design and program documents for the product and its original components. Component parts supplied by third parties are designated as ESI-PDM elements and may not have associated documents and / or 3D models. It should be noted that the lists of developed and revised documentation are determined by the annexes to the concluded agreements with the customer.

The stage of production preparation is to create sets of technological data on the product and its components in the form of ESI-PDM, corresponding to ESI-PDM obtained at the development stage. Technological data includes routing or process maps, technological instructions, control programs, typical processes and / or documentation for technological equipment. They are developed according to the design documentation or 3D-models for each component part of the product, which is the company's own development [19].

In addition, the stage of preparation for production includes procurement procedures for purchased component parts, such as standard, other products and materials, according to the content of ESI-PDM of manufactured component parts of the product. These procedures are characterized by the conclusion of contracts with suppliers.

If the development of a technological document or the purchase of a product cannot be performed due to an error in the documentation or the absence of a supplier, the employee of the technological unit or supply service fixes a comment on the corresponding design documentation [20].

Production stage means the production of parts and assembly units, including the assembly of the product itself, based on the developed sets of design and software documentation. The result is a product copy with parameter values characterizing the quality in the form of the product copy structure, as well as, if available, comments on the design and program documentation.

The operation and repair phase is characterized by sending a service request or complaint to the company. The receipt of the first document means the formation of an additional agreement to the contract, verification of the need and planning for adjustments of previously issued documentation for the components of the product. This includes planning for the manufacture of component parts of the product for the assembly of spare parts for the products necessary for the customer during the operation of the product. Upon receipt of a complaint, the employees of the enterprise investigate the causes of the failure, in accordance with which a decision is made to change the supplier of components, products for inter-factory cooperations or to adjust design, software or technological documentation.

Thus, at each stage of the life cycle, design and production procedures are performed on the basis of the generated design decisions, which allows to formulate their features and generalize approaches to creating a digital passport.

3. A generalization of approaches to creating a digital passport supporting the stages of the electronic product life cycle

The list of data is set by the information objects of PDM, ERP, MES and / or QMS systems, including EDMS, and the list of design and production procedures is set by automated processes.

This allowed to analyze the activity of enterprises of the instrument-making industry at the stages of the life cycle and form a set of pairs “information object - design and production procedure”, which are components of a digital passport.

Thus, at the stage of concluding a contract, a digital passport generally contains:

1. The procedure "Consideration and approval of an application for the development or delivery of products", which is performed by means of EDMS or PDM. In this case, information objects “Document” of the type “Application for development” or “Application for the supply of products” are created.
2. The procedure "Preparation, registration and signing of an agreement with the customer", which is performed by means of EDMS, PDM or ERP. In this case, “Document” objects are created of the “Contract with the customer” type.
3. The procedure “Registration and signing of an agreement with a co-executor”, which is also performed by means of EDMS, PDM or ERP. In this case, “Document” objects are created of the “Contract with co-executor” type.

The research results show that the objects being formed are interconnected and allow the content of the digital passport to be formed at the development stage in the form of:

1. The procedures “Development, coordination and approval of an enlarged work schedule”, which is performed by means of PDM, ERP or EDMS, forming a work schedule, including in the form of a “Document” object of the “Unified Assignment” type, and an enlarged ESI-PDM, in the form related objects designating the main components - product devices.
2. The procedures “Development, coordination and approval of the operational schedule of work”, which is performed by means of PDM, ERP or EDMS, forming a schedule of work, including in the form of a “Document” object of the “Unified Assignment” type [21].
3. The procedures "Development and design change of the printed circuit board", which is performed by CAD tools under the control of PDM, which allows to create ESI-PDM devices in the form of their circuit components.
4. The procedures “Development and design change of the product”, which is performed by CAD tools under the control of PDM, which allows to create ESI-PDM devices in the form of their designs.
5. The procedures “Updating the database of purchased components (PC)”, for the implementation of which ERP or PDM are used when synchronizing with CAD and MES.
6. Procedures "Development and change of software for the product", which allows to create the appropriate ESI-PDM using PDM.
7. Procedures “Development and change of operational data for the product”, during which the ESI-PDM created earlier is supplemented with operational documentation.
8. The procedures "Coordination, approval and delivery to the archive of a set of design and program documentation (DD and PD) for the product and its components", performed by means of PDM.

The ESI-PDM developed at the same time is called the ESI-PDM of the design presentation and is the basis for performing such work at the stage of production preparation, as:

1. The procedure “Development and signing of an application to start production”, which is performed by means of PDM, ERP or EDMS, forming a list of works, including in the form of a “Document” object of the “Unified Assignment” type [21].
2. The procedure “Development and change of technological documentation (TD) for the product”, during which the ESI-PDM of the technological presentation is created, characterized by the unambiguous correspondence of the ESI-PDM of the design presentation.
3. The procedure "Coordination, approval and delivery to the archive of technological documentation" performed by means of PDM.
4. The procedure “Recording comments and decisions during the technological preparation of production” performed by PDM, which allows to create objects “Note” associated with objects “Document” type design documentation [4, 20].
5. The procedure “Recording remarks and decisions during the planning of procurements” performed by PDM, which allows to create objects “Remark” associated with objects “Document” type of design documentation [4, 20].
6. The procedure "Preparation and registration of contracts for the supply of PC, materials and products of IPC", which is performed by means of EDMS, PDM or ERP. In this case, “Document” objects are created in the form of “Contract with the supplier”.
7. The procedure “Fixing and recording the receipt of a batch of PC, materials and products of the MPC”, which is performed by means of ERP or MES and PDM and means the formation of “Instance” objects corresponding to the received batches of products [4, 18].
8. The procedure “Formation of a production plan for manufacturing products”, which means planning work using MES tools in the form of lists of parts and assembly units to be manufactured at the factory. As a result, a production plan is generated, which is part of the “Unified Assignment” containing an application to start production.

A registered batch of products formed lists of manufactured component parts of the product allow to perform the actions of the production stage. These include:

1. The procedure “Dispatching the production process”, like the previous one, does not generate new digital passport objects, is performed by MES tools and contains lists of parts and assembly units to be manufactured in a specific production workshop. At the same time, a production plan is generated in the workshop, which is part of the “Unified Assignment” containing an application for production launch.
2. The procedure “Fixing the manufacturing operations of manufacturing parts and assembly units” is performed using MES tools, and its results are recorded as a set of “Instance” objects forming the product instance structure (SEI) using PDM tools.
3. The procedure “Recording remarks and decisions in the production process of parts and assembly units of the product”, performed by means of PDM, which allows to create objects “Note” associated with objects “Document” type of design and / or technological documentation [4, 20].

The final stage is the operation and repair, characterized by such works as:

1. The procedure "Registration of shipment of finished products from the warehouse", performed by means of ERP and / or PDM. At the same time, the PIS is supplemented by “Document” objects containing documentation on the shipment of products to the customer.
2. The procedure "Registration of the complaint and the result of the investigation of the refusal", performed by means of QMS and / or PDM. At the same time, the essence of the failure of the product instance — the “Remark” object — is associated with the corresponding “Instance” object, as well as the reason for its occurrence.
3. The procedure "Registration and control of service requests", which is performed by means of EDMS or PDM. In this case, information objects “Document” of the type “Application for service” and associated objects “Document” of the type “Additional agreement to the contract” are created. After that, using PDM, ERP or EDMS, a work schedule is formed in the form of a “Document” object of the “Unified task” type.

Consequently, k sets of digital passport components are obtained.

$$C_1 = (c_{11}, c_{12}, \dots, c_{1n_1}),\ C_2 = (c_{21}, c_{22}, \dots, c_{2n_2}), \dots,$$
$$C_k = (c_{k1}, c_{k2}, \dots, c_{kn_k}),$$

the elements of which are given by the pairs “object - design and production procedure” such that

$$c_{ij} = < D_i, Pr_j > (i = 1 \dots k,\ j = 1 \dots n_k),$$

where D_i – an information object containing data about the electronic product;

Pr_j – design and production procedure that forms a specific type of product data.

In addition, research results show that the implementation of these procedures requires the generation of design solutions for managing product data and design and production procedures based on them.

4. Features of the formation of design decisions based on a digital passport

For this purpose, the corresponding tasks were formulated, which are further associated with specific design and production procedures and stages of the life cycle. The result of each of them is the same list of components of a digital passport that are interconnected.

In this case, the tasks are characterized by lists of the analyzed parameters that determine the range of permissible values of the formed design decisions. The first of them is the task of searching for data on products and their components, which consists in analyzing the values of parameters such as:

- ✓ type of product, component — complex, assembly unit, part, kit;
- ✓ manufacturer of the product, component - own production, purchase;
- ✓ feature of the component of the product - newly developed, borrowed, IPC;
- ✓ comments on the DD - no comments, there are unworked comments, there are worked-out comments;
- ✓ the presence of comments on the PD - there are no comments, there are unworked comments, there are worked-out comments;
- ✓ availability of comments on the TD - no comments, there are unworked comments, there are worked-out comments;
- ✓ a sign of products of inadequate quality - there are no problems, there are small problems, there are serious problems.

Another task is the task of searching for data on PC, materials, products of IPC and their suppliers, which consists in analyzing the values of parameters such as:

- ✓ type of product - a standard product, other product, materials, products IPC;
- ✓ availability of products in stock - not in stock, in stock;
- ✓ the presence of prohibitions on use - there is no prohibition, a complete ban, a ban for new developments;
- ✓ availability of restrictions on use - there are no restrictions, there are restrictions;
- ✓ the possibility of acquisition - there are no suppliers, there is only one supplier, there are several suppliers;
- ✓ a sign of products of inadequate quality - there are no problems, there are small problems, there are serious problems.

The next task is the task of finding data for the development and adjustment of documentation, which consists in analyzing the values of parameters such as:

- ✓ type of document - list of elements, specification, statement of specifications, statement of purchased products, statement of electronic documents, statement of spare parts, statement of spare parts for repairs, statement of documents for repairs, ESI;
- ✓ type of ESI - functional, constructive, production and technological, physical, operational;
- ✓ comments on the DD - no comments, there are unworked comments;
- ✓ comments on the PD - no comments, there are unworked comments.

Another objective is the task of searching for data on DD, PD and TD on the components of a product to be developed or adjusted, which consists in analyzing the values of parameters such as:

- ✓ type of component of the product - complex, assembly unit, part, kit;
- ✓ feature of a component of a product - newly developed, borrowed;
- ✓ sign of the document - new DD, adjustment of DD, new PD, adjustment of PD, new TD, adjustment of TD;
- ✓ comments on the DD - no comments, there are unworked comments;
- ✓ comments on the PD — no comments, there are unworked comments;
- ✓ availability of comments on the TD - no comments, there are unworked comments.

The next task is the task of monitoring the results of the implementation of the positions of the unified task, which consists in analyzing the values of such parameters as:

- ✓ type of work - development of DD, development of PD, development of TD, adjustment of DD, adjustment of PD, adjustment of TD, purchase, production;
- ✓ controlled condition - “Under development”, “At check”, “Delivered to the archive”, “At revision”, “Litera ...”, “Completed”.

Another task is the task of managing production operations, which consists in analyzing the values of parameters such as:

- ✓ type of component of the product - complex, assembly unit, part, kit;
- ✓ comments on the DD - no comments, there are unworked comments;
- ✓ availability of comments on the TD - no comments, there are unworked comments;
- ✓ availability of products in stock - not in stock, in stock;
- ✓ sign of the production process - started, completed, suspended;
- ✓ sign of products of inadequate quality - no problems, there are problems.

And the last task is the task of creating design and production procedures, which consists in analyzing the values of parameters such as:

1) the current stage of the life cycle - the conclusion of the contract, development, preparation of production, production, operation, repair;
2) type of document from the customer - application for development, reclamation certificate, application for the supply of products, application for service;
3) the task of forming a design solution - a list of tasks listed earlier.

Therefore, for any design and production procedure at each stage of the product life cycle, the task of forming a design solution will be formed in the form of a linguistic variable, the output of which is based on elements of fuzzy logic.

5. Conclusion

Thus, the results of a generalization of approaches to creating a digital passport and the features of the formation of design decisions based on it were obtained:

1) the content of the digital passport is determined by the components in the form of pairs "object - design and production procedure";
2) the combination of components allows to create a product structure that contains not only its composition, but all related documents, including lists of procedures used;
3) the content of the digital passport is used to generate design decisions for managing product data and design and production procedures;
4) the formation of design decisions is associated with the corresponding tasks formulated in the form of linguistic variables, which allows to set the range of acceptable values for the generated solutions.

This allowed us to develop an algorithm for the generation of design solutions, according to which their desired version contains the associated components of a digital passport that fall inside the area specified by the values of the linguistic variable. The results obtained can be used to create signatures and semantics of applied unified services for a digital passport in the instrument-making industry, used in the development, delivery and maintenance of electronic products.

References

1. J. Brown. Tech-Clarity Research: The Business Benefits of Using PDM Systems // CAD / CAM / CAE Observer No. 6 (66), 2011. - pp.21-28.
2. Ed Miller, J. McCrell. Integration of PLM and ERP. Part I. // CAD / CAM / CAE Observer No. 1 (25), 2006. - pp.25-27.
3. Ed Miller, J. McCrell. Integration of PLM and ERP. Part II // CAD / CAM / CAE Observer No. 2 (26), 2006. - pp.28-30.
4. Donetskaya J., Gatchin Yu. Industrial product data management at the design stage. - Saarbrücken: LAP Lambert Academic Publishing GmbH & Co. KG, 2011 .-- 154 p.
5. Donetskaya J. Aims and objectives of developing an integrated data management system. // Information technology in professional activities and scientific work: a collection of materials of the All-Russian scientific research-to-practice conference with international participation: at 2 hours - Part 2 - Yoshkar-Ola: Mariyskii State Technical University, 2012. - 194 p. - pp. 8-11.
6. Sukhanova A., Sukhanov Yu. Thanks to Siemens technology, the development of mass production of the latest PD-14 aircraft engine, which is so needed in the Russian aircraft industry, is proceeding quickly. // CAD / CAM / CAE Observer No. 5 (97), 2015. – pp. 8-22.
7. Sukhanova A. The foundation for managing the life cycle of rocket and space technology has already been created! // CAD / CAM / CAE Observer No. 8 (92), 2014. - pp. 8-22.
8. Sukhanova A. We want to become an innovative, European enterprise for the production of dream excavators. // CAD / CAM / CAE Observer No. 2 (86), 2014. - pp. 8-25.
9. Khamitov K., Khristolyubov V. Construction of a design data management system based on Teamcenter in a geographically distributed cooperation // REM No. 4-5, 2016. - pp. 32-34.
10. Sukhanova A. Moscow Helicopter Plant named after M. Milya is ready to help other Russian Helicopters plants in developing PLM. // CAD / CAM / CAE Observer No. 1 (77), 2013 .-- pp. 8-22.
11. T. Wagner, Ch. Herrmann, S. Thiede. Industry 4.0 impacts on lean production systems. //Procedia CIRP 63 (2017). – pp. 125-131.
12. Y. Chen. Integrated and intelligent manufacturing: perspectives and enablers. //Engineering 3 (2017). – pp. 588-595.
13. A. Doshi, R.S. Smith, B.H. Thomas, C. Bouras. Use of projector based augmented reality to improve manual spot-welding precision and accuracy for automotive manufacturing. //The International Journal of Advanced Manufacturing Technology 89 (2017). – pp. 1279-1293.
14. A.E. Uva, M. Gattullo, V.M. Manghisi, D. Spagnulo, G.L. Cascella, M. Fiorentino. Evaluating the effectiveness of spatial augmented reality in smart manufacturing a solution for manual working stations. //The International Journal of Advanced Manufacturing Technology 94 (2018). – pp. 509-521.
15. M. Abramovichi, J. Ch. Gobel, Ph. Savarino, Ph. Gebus. Towards smart product lifecycle management with an integrated reconfiguration management. //International Federation for Information Processing (2017). – pp. 489-498.
16. Donetskaya J., Kuznetsova O., Tushkanov E., Kuznetsov A. Formation and analysis of engineering alternatives for an integrated electronic product description system. //Control in Technical Systems (CTS), 2017 IEEE II International Conference on - 2017, pp. 397-400.
17. Donetskaya J., Kuznetsova O., Tushkanov E., Kuznetsov A., Gatchin Yu. Mathematical model of a digital passport of an electronic product. // International Conference on Soft Computing and Measurements - 2018. - T.1. - Section 1-3. - pp. 438-441.
18. Donetskaya J. Stages of the formation of a complete electronic definition of a product and their implementation. // Navigation and traffic control: Materials of reports of the XIV conference of young scientists "Navigation and traffic control" / Scientific editor, Doctor of Technical Sciences Stepanov O. Under the general editorship of Academician V. Peshekhonov V. - SPb .: SSC RF Central Research Institute "Elektropribor", 2013. - pp.176-181.
19. Donetskaya J. Lifecycle management of technical documentation. // Materials of the XIII All-Russian Scientific and Practical Conference MORINTECH-PRACTICIAN "Information Technologies in Shipbuilding - 2012", 2012. - pp. 48-52.
20. Donetskaya J. Automating the change management process. // Navigation and motion control. Materials of reports of the XIV conference of young scientists. "Navigation and traffic control" / Scientific editor, Doctor of Technical Sciences Stepanov O. Under the general editorship of Academician of the Russian Academy of Sciences V. Peshekhonov - SPb .: SSC RF Central Research Institute "Elektropribor", 2012. - pp. 377-382.
21. Donetskaya J., Gatchin Yu. Integrated development and production management environment. // Automation in industry, No. 8, 2018. - pp. 24-30.