Digital forms of describing Industry 4.0 objects

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Abstract. The task is to project item digital model which is planned to be manufactured in cyber and physical production of the Industry 4.0. Item digital model can be classified as item digital replica, item digital shadow and item digital twin. Item digital model is a set of construction, program and technological documentation prepared electronically with automatic system of projection. Item digital shadow is a set of item digital replica documentation enhanced with mathematical equations with restrictions to describe physical and chemical properties of the item materials and its components. Details to describe the item digital shadow are defined with types of tests done with modelling and virtualization. Item digital twin is a finished form of item properties description done electronically (drawings, schemes, formulas and other) and successful physical tests of the whole cycle. The scheme is given for the item life cycle of the item designing item digital model. The scheme of production section and Industry 4.0 smart factory virtual environment components is described oriented to manufacture the items by its digital models.

1. Introduction

The development of information technologies implemented in some industries a digital approach [1, 2] in describing processes and items. The most popular today are aviation, maritime affairs, automobiles, rockets and space and some other industries to transfer the company business processes in the digital environment.

Company business processes [3, 4] as a digital object is a set of works being done in company divisions to develop or manufacture an item (technologies, materials and etc.) and then implement it. Business processes digitalizing is used to create [5, 6] in the company an informative and telecommunication environment which is used for electronic documents [7] of this company and has some means of automatic projecting (automatized) of for the product manufacturing.

Item designing or machine designing as a digitalizing object [8, 9] is a set of construction and technological, mechanical, optical, kinematics, mathematical and other description forms of material properties and components which interact. Item digital form permits to develop and create products electronically which has [10, 11] the necessary conditions to use in practice the modelling technologies and company business process virtualization.

Item life cycle in digitalizing includes three forms to describe processes or the items:

– digital replica;
– digital shadow;
– digital twin,

which may develop in time and support each other.
2. Digital replica of projection object
Item digital replica is a set of construction, program and technological documents in its electronic form to define the item appearance, properties, order of manufacturing and servicing of item in exploitation. Item digital replica has drawings, schemes and text documentation and a 3D-model (D-Dimension) of the item itself as an assembly unit.

The item digital replica documentation includes:
- technological appliances drawing which are necessary to create item in production;
- automatic work places scheme to check the quality and item functionality;
- software components with tests of integrated control and checking tests for the manufacturer plant and other.

Generally in radio and electronics item designing the item digital replica contains:
- item life cycle automatic control system for construction, program and technological documentation, including 3D-model and programs of numeric control machines prepared for the item;
- item life cycle automatic control system for construction, program and technological documentation prepared for automatic work places and technological appliances (documentation of auxiliary production);
- automatic control system of the item life cycle and control system of technological appliances life cycle;
- production, accounting and attributive data of the division name which is responsible for item development and manufacturing, the item itself and its assembly units, material consumption rates, sum indications of project and production works, name and contacts of component supplier and other.

3. Digital shadow and digital twin of projection object
Projection object digital shadow is a set of mathematical equations with a restriction system and a bunch of technical documentation in its electronic form to describe item properties relevant for the item expertise.

Item digital shadow is a more advanced form of the projection object appearance unlike a digital replica and can be formed after modelling procedures of item behavior in exploitation and the virtualization test process. Modelling and virtualization are key project procedures to automatize the activity of the designer in the Industry 4.0 digital factory.

The main goal of modelling and virtualization procedure is an equivalent of natural tests with a physical item which are being made in projection companies of the Industry 3.0. So digital shadow of the projection object describes item properties according to the tests made on its digital replica with modelling and virtualization. The first projection stages require details to be described as a digital replica and modelling cannot be done for each influence which is expected when the item is exploited. Item digital shadow is a description form being developed in time after some adjustment of mathematical models and when the documents are corrected.

The end digital form of the projection object is a digital twin. A digital twin is a set of mathematical equations with some restrictions and its electronic technical documents to describe the item properties which is good for any field of study known today. So item digital twin in its level of details is a reachable form of item description.

Figure 1 shows the scheme which in practice is used for informative development of the projection item description forms from a digital replica through a digital shadow to a digital twin.

Having analyzed figure 1 we can see that the main influence of the object description development in time as a digital shadow is for the data obtained after the item exploitation. The exploitation data (item exploitation history) can be aggregated in groups:
- data of item servicing and its repair;
- item incidents data (refusals) in its exploitation classified by the type of defects;
- current statistical data after the item exploitation (accuracy of functionality, time between failures, item tactical and technical characteristics and other) under different factors influence and other.
4. Digital description of company business processes
There are several forms to describe company business processes by the processing model, conceptual model, reference model and other. To project Industry 4.0 company the reference model is the most suitable one in its properties.

Reference model of production company is a way of description of company business processes based on the quality criteria of technological operation completion and capable of modelling with computers the activity of a smart factory. Reference model of production is from practice of business activity in industry and is used the scheme method of IDEF (Integration Definition for Function Modeling) after company business processes audit to find out the cloning procedures and lacking procedures among company divisions. The main differences of reference model are:

– it is universal, a reference model can describe a type of companies of particular activity and not a single company;
– it is repeatable, a reference model can be used again when the new digital company is created if it was obtained after the existing company;
– it is optimal, a reference model includes organization and technical and economic solutions obtained after a real business;
– it is clear, a reference model is a graphical scheme with blocks (name of company divisions) and associated links (oriented arrows to joint blocks);
– it is scalable, a reference model can be detailed to the level of some company divisions interacting with each other to complete some technological operations;
– it is transparent, a reference model is based on samples of business processes which can be used for new forms of divisions interaction;
– it is adequate, a reference model has the company structure and connections after the technological operations being realized into the company, quality control after quantity criteria (expenses for processes completion, resource load level and other).

5. Application of digital models in Industry 4.0 production

Item technical documentation in digital form requires in the production division of smart factory cyber and physical technological equipment with numeric control. To unite cyber and physical systems engaged in item manufacturing in a single route map may create the technological section production which scheme is given in figure 2.

![Figure 2. Production section scheme and smart factory components engaged in the item manufacturing.](image)

Cyber and physical systems interaction is done automatically with information exchange protocols to transfer data among the machines about technological operation completion state and data transferring to the smart factory cloud. Production data operator access is done with channels of IoT united in a single informative and telecommunication system of company virtual environment and physical machines of cyber and physical systems.

Industry 4.0 smart factory virtual environment is a set of digital models to describe:
– the item being manufactured;
– item manufacturing technological process;
– cyber and physical system (control object) to manufacture the item.

Smart factory virtual environment components scheme is given in figure 3. Interaction of digital models in virtual environment is done with program interface based on digital production semantics. Digital production semantics are formed in terms of model and processes ontology description which is the semantics dictionary of Industry 4.0.
6. Conclusion

To develop a digital replica, digital shadow and digital twin of the projection objects in the conditions of Industry 4.0 paradigm informative and telecommunication systems must be created to give the company the necessary conditions to develop digital platforms and technologies and the way of their effective interaction. Digitalizing of industrial companies sees the project and production processes as a whole new level which gives the perspectives of digital data development as a key factor of production modernization.

The transfer of project and production data in a digital format makes Industry 4.0 company functionality being independent and under the conditions of virtual factory informative infrastructure creation to unite some independent companies. Company independence is because they can transfer digital project and production data to different digital platforms without changing too much the data structure. This data acceptability is the base for digital economy projects.

Item designing and machine designing digital replicas can be viewed as a technological storage made in Industry 3.0 to transfer the project and production companies to function with the standards of Industry 4.0 where the item technical documentation is a digital shadow and digital twin.

To develop the item digital shadow and digital twin is based on informative and telecommunication system creation to aggregate and process, storage and give the designer (production operator) project and production data in its convenient form. Industry 4.0 informative and telecommunication system key properties are integrity, confidentiality, user authentication and availability of the information being transferred to all personnel of the digital company ecosystem.

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