The life cycle of technical documentation in the smart factory of Industry 4.0

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Abstract. The task is to synthesize all stages of the item designing component technical documentation life cycle in the companies of the Industry 4.0. The companies of the Industry 4.0 is a new type of project and production companies which activity is done with paperless documentation. The traditional designing procedures of construction, program and technological documentation are studied which are available today in the companies of the Industry 3.0. There is a scheme of technological documentation life cycle in the Industry 3.0 companies. It is clear that for the Industry 4.0 companies they need new forms of item designing component technical documentation which could be digital replica, digital shadow and digital twin of the item which is done in different stages of item projection. Also it is clear that new forms of electronic documents require new instrument means for project activity. There is a scheme of item designing component technical documentation life cycle in the Industry 4.0 companies.

1. Introduction

Improvement of methods and means of projection and production for the item designing components led [1, 2] to appearance of new information technologies which is the base of digital and smart factories of the Industry 4.0. Digital and smart factories are of deep automatizing of project and production procedures of the item creation which are available now thanks to the technologies of electronic documents [3].

Company electronic documents requires a special informative and telecommunication environment [4, 5] the key components of which are machines and software means of data exchange. Electronic documents are to support most of business processes [6] in the company including the projection of technical documentation.

Technical documentation projection technologies of today for the item designing components are based [7, 8] on the usage of special systems of computer aided design which helps the designer to prepare all types of documents which are parts of construction, program and technological documentation. Those technologies are instead now of paper documents which require all schemes, drawings and text documentation to be prepared without any CAD (Computer Aided Design) mean.

For the Industry 4.0 [9, 10] companies the technologies of electronic documents is only the beginning which will be developed by implementation into project and production activity the new forms of item properties description as a digital product. Those new forms of description require mathematical theories and methods which show the components and material properties as equations and non-equations.

Digital product properties mathematical forms of description may lead to the development of imitation modelling and virtualization which helps to change in project and production companies of the Industry 4.0 some business processes including the item manufacturing and its natural tests.

The implementation of digital product properties mathematical forms of description into project and production activity alongside with electronic documents require to re-establish some stage of the item...
life cycle from an Industry 3.0 company. They need to re-asses the construction, program and technological documentation and in the future it will help to create item designing component digital replica, digital shadow and digital twin.

2. Technical documentation life cycle in the Industry 3.0 company

Item designing component technical documentation in the Industry 3.0 company is done electronically and classified in three types of documents:

- construction documentation (CD);
- program documentation (PD);
- technological documentation (TD).

The development of technical documentation is done in the stage of the item structure projection according to the requirements of the technical task (TT).

Construction documentation is for description of mass and dimensions characteristics of the item which are done with standards with rules how to create those documents.

Construction documentation is a set of electronic documents which includes:
- schemes;
- drawings;
- text documentation
  which a designer creates with computer aided design systems of projection and technical means which is a part of automatic work place in a project company.

Program documentation describes algorithms of item functioning in exploitation and it has some special industry standards. Program documentation is a set of files and programs which include:
- algorithms;
- text documentation;
- machine code of the files being executed
  which is done by the designers of the items controlled by program.

Technological documentation describes production processes of item manufacturing and it has some special industrial standards. Technological documentation is done after its construction and program counterparts. The technological documentation includes:
- schemes;
- drawings;
- text documentation
  which is prepared for the processes of item manufacturing and for technological equipment of the production process. The content of technological documentation describes which actions the Industry 3.0 company worker must do to create the item itself and its assembly units.

The technical documentation quality for the Industry 3.0 item designing components is evaluated by:
- a norm controller who checks each type of documents of CD, PD, TD which is a set of rules and norms in standards;
- a designer who conducts a set of tests with an item sample manufactured after its CD, PD, TD in the company production division.

Results of visual assessment of technical documentation each type and results of natural tests which show some discrepancies in quality of item functioning from the one of technical task could be a good base for some modifications of CD, PD, TD. The iterative process of technical documentation quality assessment in the Industry 3.0 company must be repeated until the following results are achieved:
- rules how to make all documents of CD, PD, TD are completed according to the state and branch standards;
- item properties which are results of test with its quality and quantity evaluation according to the requirements of this item development technical task.
Figure 1. Technical documentation life cycle scheme in the industrial companies of the Industry 3.0

The scheme of technical documentation life cycle being done in the Industry 3.0 company is given in figure 1. Having analyzed the figure 1 we can say that item construction and program documentation being developed in the Industry 3.0 company in parallel according to the requirements of technical task. Technological documentation is being developed after its construction and program counterparts.

The correction of technical documentation after the each type of documents by a norm controller analysis results which are done separately for CD, PD, TD. The changes to CD, PD, TD after its sample tests are done at the same time.

3. Technical documentation life cycle in the Industry 4.0 company
Item designing component technical documentation made in the Industry 4.0 company is a digital product of the company projection activity which is represented in one of the following forms:
- item digital replica which is technical documentation like CD, PD, TD done electronically after project procedures which are quite like the procedures of the Industry 3.0 company;
- item digital shadow which is its CD, PD, TD with some mathematical equations to describe its physical and chemical properties of materials and its components which is the part of the item;
- item digital twin which is the ideal form of item description done first as a detail accepted after item digital shadow.

Forms to describe items as digital replica, digital shadow and digital twin is a specific thing of the Industry 4.0 and manifest the implementation of new knowledge in different fields of applicable and fundamental sciences into project activity of a digital factory.

To prepare the item digital replica electronically they use computer aided design systems and technical means to automatize the project activity which are like the components available now in the Industry 3.0 company.

Item digital shadow is made after modelling of the item 3D-model and its assembly units into a virtual environment which is a software of work station of the Industry 4.0 digital factory. Modelling tests of digital shadow is done according to the requirements of the external factors influences and its technical task for the item development.

Positive results of the digital shadow modelling tests is the base to create the item sample in cyber and physical production. The item sample is tested with natural tests in the test center of a digital factory to approve the properties and technical characteristics of the item being good for the requirements of the
item development technical task. Results of modelling tests of the item digital shadow and results of physical tests of the item sample is a reason to modify technical documents of the item digital shadow.

Item digital shadow is an item description form from which the documentation will be transferred to the Industry 4.0 smart factory for its serial production. Serial items being exploited have some loads which are higher than the ones from the technical task so that why the further improvement of the item documentation is required which will be supported through the whole life cycle of the item.

Notes after the item exploitation (a bunch of items) is a reason to change the item digital shadow and after some iterations the digital twin will be created which includes:
- technical documentation (CD, PD, TD);
- mathematical equations which are good for real exploitation conditions to describe masses and dimensions of the item and its physical and chemical properties.

Digital replica, digital shadow and digital twin is a result of separate project activity in the Industry 4.0 company and they are stored in the company cloud storage. Technical documentation life cycle scheme in the companies of the Industry 4.0 is given in figure 2.

![Figure 2. Technical documentation life cycle scheme in the industrial companies of the Industry 4.0](image)

### 4. Conclusion

To describe item properties as mathematical equations is a perspective direction for the item technical documentation life cycle stages development being done in the Industry 4.0 company paperlessly and humanlessly. Main components of those mathematical equations for the item designing components are differential and integral non-equations to define physical laws of optics, radio signals electronics, mechanics, thermodynamics and other.

The components of mathematical equations (non-equations) is a part of the item 3D-model according to its construction, program and technological documentations to describe masses and dimensions of the item and its physical and chemical properties and also optical, cinematics and other properties of the assembly units.

To describe an item as its mathematical model will help to create the libraries of assembly units bases (assembly units of wide application) which helps to reduce the time of manufacturing and to increase the quality of the items being developed. Mathematical equation in this case is a universal mean which can be implemented into the program environment of modelling and virtualization to support the test procedures of the item digital models.

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