Using skeleton geometry of parts and assembly units of aviation pipeline for digital shadow realization

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Abstract. The paper has deals with the skeleton geometry as a bases for parts and assembly units of aviation pipeline digital shadows. This digital shadow a used for storing useful information from processes of part production and assembling this parts into units. Information support allows you to manage design tolerances. Selected representation in skeleton geometry model already prepared for integration into specialized ontology.

1. Introduction
Today a wide area of high tech production, such as aviation, a widely uses information technology on all stage of life circle. Particularly on stage of design and technological preparation of production.

Modern information technology effectively used for V-model life circle [1,2] realization with development on mathematical models of the product and technological processes. In spite of mathematical models with high accuracy using the technological process it may be very complicated and some deviations can’t be predicted. Therefore useful to obtain and save data, that was received in production processes. In this situation appear the problem of obtaining and saving the necessary data. To solve this problem, it is necessary to identify the criteria of necessity and sufficiency for main parameters of technological and production processes that affect quality of production. After which the criteria are linked with results on the basis of "if - then" or more complicated principal that described the situation of production process, product construction design, material and other factors that can be influenced on quality.

One of the most important of the product quality criteria is compliance with design tolerances for parts and assembly units. Especially this criterion very important for parts and assembly of aviation pipeline systems because of their long length.

2. Preliminary Bases
The idea of digital twin concept was presented by dr. Michael Grieves in 2002 at conference in Michigan. This term is also used in NASA.[3]

The direction of creating digital twins is today an urgent and actively developing industry and universities. Creating a digital twin allows you to increase the level of competitiveness of the enterprise by increasing the speed of development of the design and technological processes on digital twins of products and industries. In Russia, the main center of the NTI responsible for the creation of digital twins is Peter the Great St. Petersburg University [4]. The following universities can be distinguished among the world centers for research and development of digital twins: Florida Institute
of Technology, University of Michigan, Stanford University, as well as enterprises: Siemens, NASA, Dassault Systemes, General Electric, PTC, Boeing, Airbus, Volkswagen.

The uses of digital twins concept is very complicated and for our purpose will be used the part of this concept which named digital shadow. This is light concept which building without using physicals calculation. This reduces the performance requirements of computer technology in the case of a larger set of parts.

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In this paper will be used next described of the digital shadow:

«Digital shadow – all useful data, which can be stored in production process and reuse on life-cycle stages for improve quality, reduce coast and other useful effects».

This data also can be used in the development of new products in the future.

3. Related Works

The design and development of an aircraft is a multidisciplinary activity, which is based on intensive using of various geometrical models of parts, assemblies and their complexes in different stages of the corresponding lifecycle. [5]

A questions of using a geometrical modeling in aviation design and production was reviewed at works [6–8].

The skeleton models was reviewed at works [9,10]. This models used to adjustment the coordinate system and allow to save professional experience in precedent model, which ready for reuse.

The graphical representation skeleton models a represented in figure 1.

![Figure 1. Skeleton models for an assembly unit (P, P1).](image)

Where also used a symbol model which for fragment presented in figure 1, its part defining the plane of welding has the following description:

\[
\{\text{det\_number1; connection\_type; } d_i; \ P_{i1}, P_{i2}, P_{i3} \}$
\[
\text{det\_number2; connection\_type; } d_j; \ P_{j1}, P_{j2}, P_{j3}\}
\]

where \(\text{det\_number}\) – part identification number;
\(\text{connection\_type}\) – type of part connection used (for example welding, fitting, bolted connection threaded connection and other);
\(d_i\) – diameter of the corresponding circle;
\(P_{xy}\) – points of the contour to be assembled.

The coordinate adjunctions is described at works [9,11,12].

4. The Tools and Equipment for Digital Shadow Realization

As noted above the most important of the product quality criteria is compliance with design tolerances for parts and assembly units. There is a need to measure of tolerance for parts and assembly units that
used in life cycle. Information about measures today stored without special structure that can be reused on next stage of lifecycle.

This problem can be solved with new geometrical representation building. The representation a production process data could be a compact size prepared for database storing as digital shadow and reuse on lifecycle stages. The solution to this may be using skeleton geometry. Where points of skeleton geometry are the coordinates which obtained as a result of control of parts and assembly units. For control operations at aviation production are used various controls instruments such as laser trackers, controlling machines and others. Data obtained from parts and assembly units of production processes are stored as skeleton models in the enterprise database. Physical parameter data sets form digital shadows of parts and assembly units of aviation pipeline.

Example of related physical parameters of parts and assembly with digital shadow which represented is a set of skeleton models represented in figure 2.

![Figure 2](image)

**Figure 2.** Example of related physical parameters of parts and assembly with digital shadow which represented is a set of skeleton models

In database a digital shadow of part and assembly is safe at format that represented in table 1.

| Part Number ID | Production number | Skeleton model | Symbolic model |
|----------------|-------------------|----------------|----------------|
| XXXX.XXXXXXX.XXX | XXXXXXXX          | TRP.XX.XXXXXXX | \{det_number1;connection_type; di; Pi4 , Pi5, Pi6 \} |
|                |                   |                | \{det_number2; connection_type; dj; Pj1, Pi2, Pi3\} |
The method of digital shadow realization consist is next steps:
1. At design stage the definition of tolerances and quality criteria.
2. Building a skeleton model of parts and assembly units.
3. Collect data from production process.
4. Save data in database in useful precedent format. [13,14]
5. Analysis and uses data for technological process correction or improvement.[15]
6. Using data in development of new product.

From a set of skeleton part models there is a possibility to create of a skeleton models of assembly and pipeline tube system. Also there is a possibility to simulate a various assembly models with goal to do optimal assembly of aviation system. Where the optimal criteria is may be constructional tolerance and dimensions which important as quality parameters.

An example of a pipeline system in the form of skeleton models is represented in figure 3.

![Figure 3. Example of pipeline system in the form of skeleton models](image)

In assembly simulation uses data from technological process to calculate the tolerance deviations at assembly. The formula for equations is represented bellow:

\[ \Delta_{\text{Assembly point}} = \sum_{i=1}^{n} (\Delta_{\text{part point}} + \Delta_{\text{operation}}) \]

where \( \Delta_{\text{Assembly point}} \) - tolerance deviations of point on aviation tube assembly;
\( \Delta_{\text{part point}} \) - tolerance deviations of point on aviation tube part; and
\( \Delta_{\text{operation}} \) - tolerance deviations which appear at technological operation which also included.

5. Conclusion
The article discusses one of the options for creating digital shadow of parts and assembly units of aviation pipeline.
The main feature of the Digital Shadow using is accumulation useful data from production process in the enterprise database.

In practice realization a parts and assembly of aviation’s pipeline digital shadow allow to improve technological parameters in assembly operations through calculations of optimal part set for assembly unit. Also a set of skeleton models allow to calculate of pipeline system tolerance deviations.

Such sets of digital shadows allow to accumulate useful professional experience in the form of case models which can be used when developing new products. Especially at the design stages where a digital twin of products and processes can be created.

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