Computer-Assistant Design Verification

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Abstract

Investigation of the quality management problem in design documentation development with the hierarchy analysis method has revealed a conflict of interests between the designer and the standard-compliance verification controller. The proposed IDEF model of design verification procedures helps obtaining basic principles for creating an automated design verification workstation based on the expert systems approach. Implementation issues are also covered.

Keywords: *quality management problem, design documentation, standard-compliance verification controllers*

1. INTRODUCTION

Issues of quality management have always been extremely important in any industry. It is obvious that a significant contribution to the total quality of the product is made by the quality of design documentation (DD). DD includes electronic 2D and 3D part and assembly drawings, bills of materials and other related documents mostly developed by designers.

DD can be considered as a virtual model of a real object. DD always includes a certain number of errors that are passed along the entire lifecycle of the product. In computer-integrated manufacturing the passing is performed by CAM systems, which as a rule do not add more errors in the process of NC codes generation. Another option is manual transformation of the drawing into a manufacturing process that inevitably leads to more human errors. Finally in both cases the manufacturing equipment adds more errors.

It is clear that the earlier an error is made the more difficult to find it and the more loss it causes. In [1, p.35] it is indicated that the effectiveness of quality control at the design time is only 46% (over 50% of designer's errors remain unnoticed), 63% at making the prototype, and 80-100% at serial production. That is why there is a need to sharply increase the quality of electronically generated DD.

2. DEFINING DD QUALITY

There are several approaches to defining the quality of DD [2,3]. Their common feature is a clear separation of design quality and manufacturing quality in order to avoid remarks like "it's easy to make a low-quality product with high-quality drawings". Further investigation has revealed three levels of managing DD quality (Fig. 1).

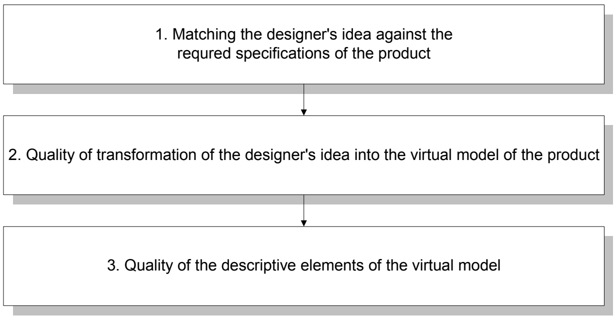


Figure 1: Levels of DD quality.

First, there is a level of matching the designer's ideas against the expected specifications of the product. This level is a creative one and is hard-to-analyze although there exist some methods like brainstorm, inventor problems theory etc. Second, there is an issue of transformation the designer's idea into the virtual model. The transformation is subjected to human errors. Using modern solid modeling systems may invoke a reverse effect: high difficulty of making certain elements or insufficient experience may lead to changing the design for the worse. For example, it [8, p.2] we read: "*High labor consuming of creating complex surfaces and axonometric projections can make the designer to remove or simplify them. It causes difficulties with understanding the project or even damage the performance of the project*". Third, DD contains many so-called descriptive elements being dimensions, tolerances, specifications, etc. Their correct, standard-compliant designation is vitally important for the manufacturing process and the quality of the final product.

The specified levels correspond well to the aspects of DD quality indicated in [9]: "quality of engineering content, descriptive content and physical condition". Note that for electronic DD the aspect of physical condition is irrelevant.

To sum up we may introduce a general definition of **DD quality:** *degree of correspondence of the virtual model features to the product features*. Virtual model features are obtained by calculation of its parameters like FEM stress analysis, kinematics modeling, etc. Such a definition clearly separates the errors in DD from the errors added at the later stages of the product's lifecycle.

3. METHODS OF DESIGN VERIFICATION.

Russian Unified System for Design Documentation (known as ESKD) offers several design verification procedures: layout and formatting verification, manufacturability verification, metrological verification, and standard-compliance verification (SCV). As it is noted in [4, p. 10] only 10% of DD errors are fundamental design errors while 90% are non-compliance with the drawing and engineering standards. Fundamental design errors are extremely difficult to find automatically and this problem has not been solved yet. On the other hand most errors are deviations from the standards that can be and should be detected and corrected in the course of the design verification procedures.

It can be shown that SCV is most difficult because the number of standards in about 50 next to just one standard for manufacturability and metrological verifications. SCV is highly labor-consuming and requires special skills. Moreover, at many industrial enterprises in Russia in the last decade the SCV departments were closed down due to financial problems. As a result a significant part of DD under development needs extra re-working after making the prototypes. Need for skilled design verification specialists (usually called SCV controllers) impairs product quality and competitiveness of Russian industry. To correct the problem it is necessary to develop computer-based tools for SCV and express e-learning.

4. PROBLEM STATEMENT.

There is a problem of DD quality management based on computer-assistant tools for SCV and on developing an e-learning system for additional training of designers and SCV controllers.

The very organization of SCV implies an antagonism between the designer and the SCV controller. The conflict of interests has been studied using the hierarchy analysis method developed by T. Saaty [5]. According to the method the general goal of the system, its forces and actors have been specified. The actors have their own local goals and extreme behavior patterns aimed at reaching the local goals. The final chart is shown in Fig. 2. The chart has allowed to highlight the conflicts of professional interests between all three actors.

Correctness of the proposed designer's behavior is backed by the data [1] saying that the designer can detect no more than 2/3 of his/her errors while the remaining 1/3 goes to the next step of the lifecycle. The behavior patterns for SCV controllers and DD consumers are confirmed by analyzing activities of several industrial companies.

The conflicts "designer – SCV", "designer, SCV – DD consumer" can be resolved with the help of an automated workstation for both designer and SCV controller. Such a workstation should perform the following:

1. Designer's workstation: forced compliance with the standards within the CAD package (e.g. automated dimensioning, insertion of correct tolerances, roughness signs, etc.). Most CAD packages feature such compliance so we do not have to elaborate on this.

2. SCV workstation: tools for online design verification and tracking errors integrated into an electronic docflow/workflow system. These tools must be oriented at low-skill users who might be unaware of many SCV issues.

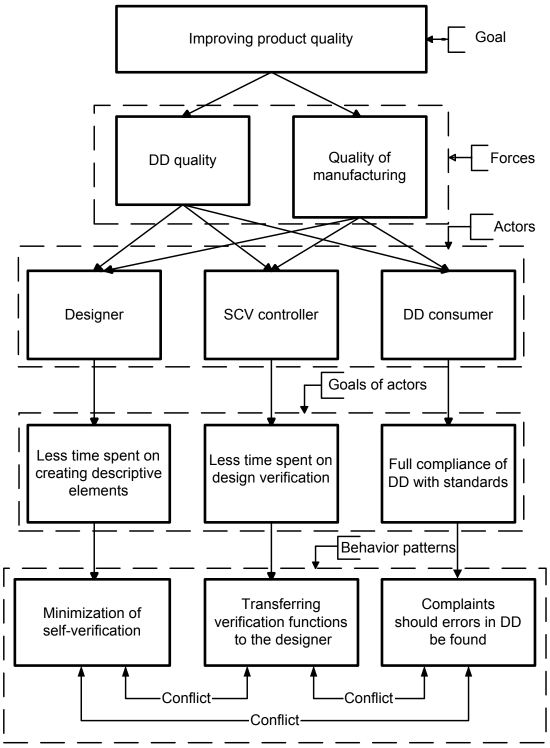


Figure 2: Conflicts of professional interests.

5. SCV FUNCTIONS.

To develop the structure of a SCV workstation we have analyzed the functions of SCV controllers listed in GOST 2.111-68 and company standards. IDEF methodology [6] has been used to produce A0-A2 diagrams (Fig. 3-5) that show subtasks of the SCV controller and ways of carrying them out.

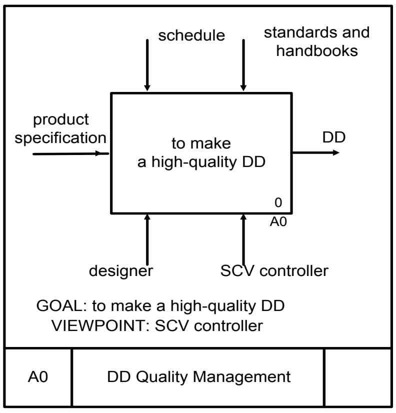


Figure 3: Diagram A0 of the IDEF model.

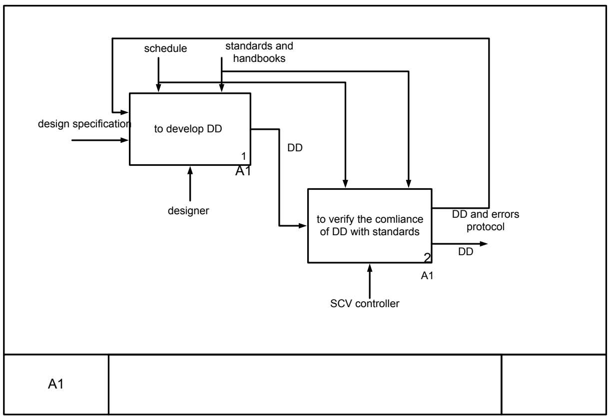


Figure 4: Diagram A1 of the IDEF model.

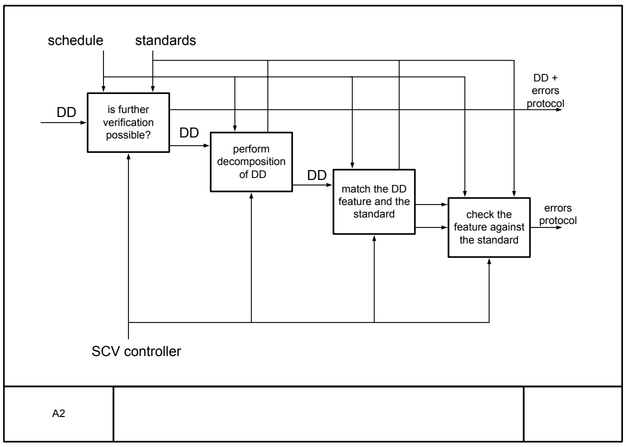


Figure 5: Diagram A2 of the IDEF model.

The A2 diagram has led to the general structure of a SCV workstation shown in Fig.6. It is also based on a so-called productive system being a subclass of expert systems [7].

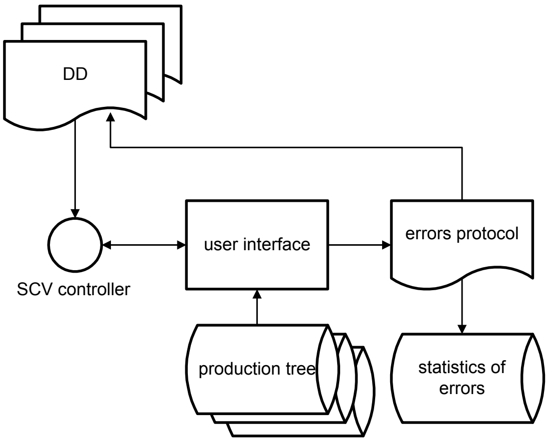


Figure 6: Structure of a SCV workstation.

6. PRODUCTIVE SYSTEM DEVELOPMENT.

Each standard is represented by its production tree. The SCV controller checks DD following the tree. Errors found are marked in the errors protocol. The protocol links a textual description of the error to its location on the drawing. The system gathers statistical data on errors in DD, which allows implementing a self-learning function. Statistics includes most typical errors made by each designer. Having such information the system upon verifying some DD suggests checking it first against the requirements usually violated by the designer who has developed the DD.

The set of ESKD standards can be divided into general ones that are applied to all kinds of DD, and specific ones applied to DD for certain kinds of objects like gears, springs, electric circuits, etc. That is why we have developed a classifier of drawing standards.

Production trees are formed as a “question–answer” sequence. Each question has just two answers: yes and no. Some of the tree branches are blind ends that correspond to error messages. Using the productive tree the SCV controller answers the questions one by one. If an answer leads to an error message its test is automatically transferred into the CAD package and the error location is marked. The mark includes the error message that can later be viewed by the designer. Fig. 7 shows a fragment of the tree representing the standard GOST 2.307-68 "Dimensioning and Tolerances".

The proposed system can be used for learning. The user browses the tree while analyzing a tutorial drawing, which contains errors. The number of errors the user can detect reflects user’s skill.

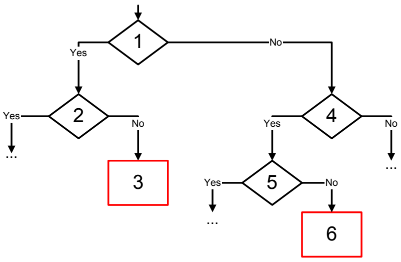
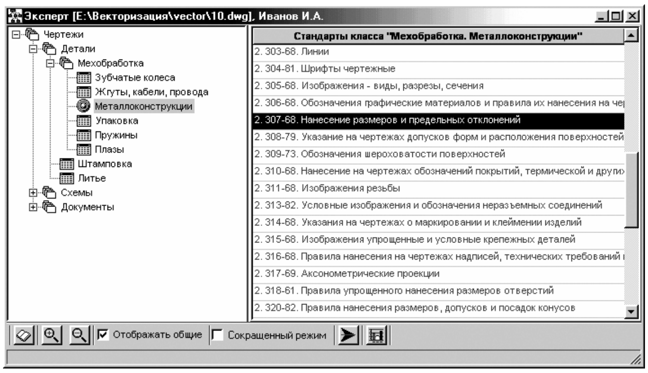


Figure 7: A fragment of a production tree.

Explication:
1. Does the dimension belong to one of the following categories:
- one of the dimensions of a closed dimension chain;
- dimension borrowed from a workpiece drawing;
- dimension defining the position of features that are treated jointly with another part;
2. Is the dimension marked with "*" and is the text "* Reference dimension" present in the specification?
3. Error: the dimension is a reference one and must be marked with "*". The specification must include the text "* Reference dimension".
4. Are the dimensions represent a closed chain?
5. Is at least one of the dimensions on the chain marked as a reference one?
6. Error: on a closed dimension chain at least one dimension must be marked as a reference one.

7. IMPLEMENTATION.

The implementation of the system is SCV workstation Norca 1.0 (Russian acronym for “design verification”) integrated with AutoCAD2002. Its main screen is shown in Fig. 8.



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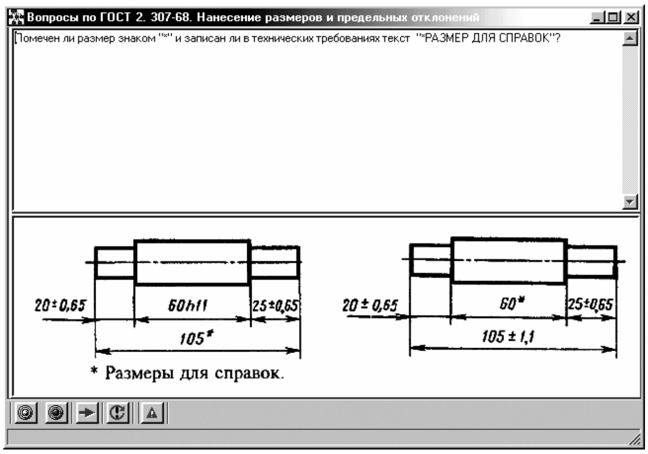
Стандарты класса "Мехобработка. Металлоконструкции"

2. 303-68. Линии
2. 304-81. Шрифты чертежные
2. 305-68. Изображения - виды, разрезы, сечения
2. 306-68. Обозначения графические материалов и правила их нанесения на че
2. 307-68. Нанесение размеров и предельных отклонений
2. 308-79. Указание на чертежах допусков форм и расположения поверхностей
2. 309-73. Обозначения шероховатости поверхностей
2. 310-68. Нанесение на чертежах обозначений покрытий, термической и други
2. 311-68. Изображения резьбы
2. 313-82. Условные изображения и обозначения неразъемных соединений
2. 314-68. Указания на чертежах о маркировании и клеймении изделий
2. 315-68. Изображения упрощенные и условные крепежных деталей
2. 316-68. Правила нанесения на чертежах надписей, технических требований
2. 317-69. Аксонометрические проекции
2. 318-61. Правила упрощенного нанесения размеров отверстий
2. 320-82. Правила нанесения размеров, допусков и посадок конусов

Figure 8: Main screen of Norca 1.0.

A SCV controller selects the kind of DD being checked in the classifier tree. The system displays the corresponding list of standards. For each standard a verification dialog (Fig. 9) can be invoked. If necessary a question is explained by a picture.



Вопросы по ГОСТ 2. 307-68. Нанесение размеров и предельных отклонений

Помечен ли размер знаком "*" и записан ли в технических требованиях текст "*РАЗМЕР ДЛЯ СПРАВОК"?

Figure 9: Verification dialog window.

Should an error be found *Norca* automatically transfers the error message into AutoCAD. The controller marks the errors right on the drawing (layers are used). The designer who has to correct the error is able to view the message linked to each error mark. After the error is corrected the mark is easily removed.

One more function of the system is gathering statistical data on designers’ errors. The system displays total number of error made by each designer within a certain period of time as well as it displays the list of common errors for each designer. Statistical data help evaluating designer performance and re-train or discipline the designer when necessary.

8. CONCLUSION.

Further research is aimed at expanding the system and development of text analysis tools for automated generation of production trees from the texts of standards.

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