Recognition of structural elements of mechanical engineering as a solution to data formalization problem

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Abstract. The paper discusses a typical example of recognizing a sheet metal part containing 2 structural elements. According to the developed recognition algorithm, a software module was implemented for automated recognition of structural elements in a 3-dimensional model of parts with the *.stp extension, which allowed working not only with models made in the Siemens NX system, but also, in general, with almost any 3D models exported in this format. The result of recognition can be used to develop systems that design technological processes for the production of mechanical engineering products, including at aircraft production enterprises.

1. Introduction

The classification of parts produced at factories includes thousands of different types, shapes and sizes. Every year their number only grows, under the influence of the development of technology for the production of new details. In this regard, we can state that there is a need to systematize all the variety of details. The process of systematization becomes possible through the implementation of the classification of existing and new elements of the model. Classification is important in the management of the quality and variety of parts, as it promotes the systematic study of parts, rational organization of production, effective quality control work and ultimately leads to the decrease in the cost of the final product.

2. Results

The algorithm for the qualitative assessment of products can be conditionally divided into 2 stages:

1. the analysis of the geometric characteristics of structural elements included in the structure of the product;
2. the analysis of the capabilities of an enterprise having a production basis for the manufacture of individual structural elements and the product as a whole.

The idea of product analysis is based on the assumption that any product (diaphragms, ribs, angle bars, etc.) can be formalized as a set of structurally connected in a certain way and having its own set of characteristics by analogy with an assembly unit, which consists of individual products connected in a certain way.

Thus the sheet part shown in Figure 1 can be described by a set of structural elements included in it: wall + flanging, flanging.
In order to ensure the possibility of an unambiguous definition of a product through its structural elements, it is necessary to develop a classifier of possible structural elements.

**Table 1. Typical classifier of structural elements**

| Code of structural elements | Name of structural elements of a part                           |
|-----------------------------|-----------------------------------------------------------------|
| 01                          | Flanging on a flat surface                                      |
| 02                          | Flanging on a curved surface                                    |
| 03                          | Blind flanging on a flat surface                                |
| 04                          | Blind flanging on a curved surface                              |

In this classifier, only one structural element (SE) is presented. However, the list of SEs that should be included in the classifier is individual parameters for each production, taking into account their production capabilities.

Such a representation of a part through a set of structural elements is enough for human understanding, but not enough for automating recognition by a program method, since the very concept of a “structural element” is empirical.

The electronic model of the product is presented in the form of a hierarchical structure in Figure 2. In this case, the structural elements are uniquely defined through the graph set of “edges-surfaces”, where the edges of the 3d-model act as the vertices of the graph and the surfaces of the 3d-model act as the edges of the graph.

The flanging is a structural element that increases the rigidity of the wall of the part, in addition, it can reduce the weight of a part. In the aircraft industry, the following types of flanges are distinguished: type 1, type 2 and type 3.

The process of formation during flanging is performed by thinning the material. When making flanges of type 1 and type 2, there is uniaxial tension in the circumferential direction, the degree of deformation is proportional to the increase in the diameter of the pre-formed hole. The examples of flanges are shown in Figure 3.
Figure 2. Electronic representation of a 3D product model

Figure 3. Type of flanging

During the production of disc flanging of type 3, the hole is punched after the flanging cavity has been formed. When a blind flanging is formed, uniaxial stretching occurs in the meridian direction. The process of formation is carried out by thinning the workpiece material, including the areas surrounding the flanging. This aspect must be taken into account when placing adjacent structural elements when assigning dimension A (Figure 3), in order to prevent excessive thinning of the wall.

It is determined more unambiguously despite the geometrically more complex shape than, for example, near the wall from a technical point of view. The structure of flanging of type 1 consists of a flat surface bounded by two circles, which, together with two more circles, form cylindrical surfaces.
of the beads flowing into toroidal surfaces. Toroidal surfaces have a common center, therefore, for automatic recognition, it is sufficient to find two toroidal surfaces with a common center in the part structure. Next we consider the classification by the type of flanging. The graphical structure of flanging of type 1 is shown in Figure 4.

![Figure 4. Structural element of flanging of type 1](image)

In fact, the above mentioned aspects are relevant for all structural elements with a similar production method, such as a rift.

According to the developed theory, a program was implemented that allows recognizing flanging of type 1, chamfers, fillets and holes in parts with the extension .stp, which allows working not only with Siemens NX models, but also, in general, with almost any 3D models exported into this format. Figures 5, 6 show the operation of the program.

![Figure 5. Studied model](image)
Figure 6. Program interface

As we can see from Figure 6, the program interface includes a file selection button, a button for starting the recognition process, graphic diagrams indicating the type of the recognized element and the parameters to be determined, the blocks where information about the recognized elements is given and a block indicating the path to the current file.

3. Conclusion
The given example shows correct recognition of three different flanging on a part that does not have a construction tree. This approach can be implemented not only on parts made of semi-finished sheet products, but also on any other SE used in other industries. According to the results of the study, a Certificate for computer program No. 2019665155 dated 20.11.2019 was issued.

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