How to cite this article:

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Title of article: "Analysis of the accuracy of the reproduction of the solid model from the parametric surface in the module Reverse Engineering NX system"

Mechanik, No. 7 (2019)DOI: <https://doi.org/10.17814/mechanik.2019.7.59>

Analysis of the accuracy of the reproduction of the solid model from the parametric surface in the module Reverse Engineering NX system

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An analysis of the accuracy of generating a solid mode based on the created surfaces is presented. In the process of creating a digital model, reconstructive engineering methods were used. The accuracy of mapping of the created solid model was determined on the basis of surface models generated by changing the tolerance value of triangles

KEYWORDS: *CAD systems, reverse engineering, solid model*

Introduction

In many industries, including in the aviation and automotive ones, demand for reconstruction of existing products using reverse engineering techniques is increasing [2, 5]. The reconstructed geometrical and dimensional form of the detail makes it possible to learn its features and mode of operation, which is important especially when no documentation of the object exists [4].

With the development of CAD/CAM technology, creating solid 3D CAD models of existing objects began to play an increasingly important role in reverse engineering [6]. One of the easiest methods to reproduce a prototype into a solid model is to collect data in the form of a point cloud using measuring tools - including coordinate measuring machines, optical scanners or even computer tomographs [1, 3]. Based on this data, surface models (consisting of a triangle mesh) followed by solid models, are created. Restoring an existing object to a surface model and converting it to a 3D CAD solid model allows it to be saved as a file, e.g. in the *.prt format. This form of the file makes it possible to develop 2D implementation documentation, as well as perform finite element calculations using the CAE (computer aided engineering) program and to develop a technological process in CAM (computer aided manufacturing) software.

The disadvantage of reproducing a solid model is its certain geometrical imperfection in relation to the quality of generated surface models. Therefore, there is a need to improve the geometric form of a solid model by changing the surface properties of the model, from which the solid object is created. These actions can help improve the structure relative to the initial physical model.

Analysis object

The reference model was created using commands from the Modeling module in the Siemens NX CAD system. The model consisted of straight, convex, concave, sloping and rounded surfaces (fig. 1).

It was exported to a *.stl (standard triangle language) file as a binary output file. Models saved in this format are an approximation of a surface model consisting of triangles. The number and size of these triangles

are defined depending on the complexity of the surface. Each of the individual triangles is assigned three edges that join together in three nodes. It is not possible for the node of one triangle to be on the edge of the next, tangent triangle (fig. 2a), thus joint corner connection is only possible in nodes. In addition, each triangle is assigned a vector perpendicular to the surface, with the orientation corresponding to the right hand rule. The resulting surfaces have a positive or negative value. This is important when performing actions on the model (positive side of the triangle is the outer part of the created solid, and negative - inside of the model).

Fig. 1. Reference model: a) model outline, b) 3D model

Fig. 2. Example geometry of the model saved in the *.stl file: a) surface form of the model built of triangles, b) graphically illustrated value of the t parameter

When exporting the reference model to surface models in the *.stl format, a variable value of t was used - from 0.01 mm, every 0.01 mm, up to 0.1 mm. The t parameter means the distance between the edge of the surface of the reference surface model and edge of the imported surface consisting of triangles (fig. 2b). The adhesion tolerance of the exported surface model was left unchanged (0.08 mm).

Creating a solid model

Based on the surface models obtained as a result of exporting the reference model by changing the value of the parameter t (fig. 3), solid models were created (using the tool from the Modeling module). The creation process consisted of generating a cross-section of the imported surface built of triangles. The cross-section consisted of points 0.05 mm apart. Using the created points, cross-section curves from 1 to 20 were created (fig. 4). Values of errors in creating these curves are shown in figs. 5 and 6.

Fig. 3. Example images showing the influence of the variable value of parameter t on the triangle mesh after exporting the reference model to the *.stl file: a) $t = 0.01$ mm, b) $t = 0.05$ mm

Fig. 4. Generated cross-section of imported surface from *.stl file, consisting of points spaced 0.05 mm apart

Fig. 5. Graph of the maximum error value for creating curves depending on the reconstructed section curves

Fig. 6. Graph of the average error in creating curves depending on the reconstructed section curves

The matched spline curves created, with the number of poles equal to 6 and the number of segments equal to 1, were used to create the solid cross-section. The solid model was obtained based on the rotation of these closed curves using the curve rotation command from the Modeling module in Siemens NX software. Modeling distance tolerance was 0.01 mm.

Accuracy of solid model reconstruction

After restoring the solid models, a coverage analysis was performed with a reference model, based on which the surface models were created. For this purpose, the command from the Analysis menu in the Reverse Engineering module was used. It allows to display data deviation values between a curve or surface and a reference object. In order to visualize the level of accuracy of the reconstructed solid model, the Color Map and Needles options (in the same module) have been activated. Deviation maps of the reconstructed solid model from the reference model depending on the t parameter are presented in figs. 7.

Values of the maximum and minimum deviations between the solid model and the reference model are shown in fig. 8. Symbols $t1$ to $t10$ mean values of parameters t from 0.01 mm to 0.1 mm (every 0.01 mm). It can be seen that deviations between the reference model and the solid model created were from 0 to positive, equal

to a maximum of 0.034 mm, while the maximum negative value was in the range of up to 0.05 mm. With the increase in the value of the parameter t , value of deviations increased on the reconstructed solid model.

Fig. 7. Map of deviations between the reconstructed solid model and the reference model
a) $t = 0.01$ mm, b) $t = 0.1$ mm

Fig. 8. Values of maximum and minimum deviations obtained on the basis of the difference between created solid model and the reference model

Conclusions

Based on the obtained values of deviations between created solid and reference model, it can be stated that the accuracy of reproduction of the solid model is strongly influenced by the type of mesh. The impact of the solid model reconstruction method is negligible, taking into account the obtained maximum values and average reconstruction errors. Application of variable value of the t parameter resulted in different grid configurations of generated surface model. The accuracy of the solid model mapping decreases as the value of the t parameter increases - this is due to limited possibility of mapping the curves. In addition, generating a solid as a *.stl file format in the form of a triangle grid results in the curves being presented as parts of regular polygons with the number of sides depending on the recording resolution of the model. Most CAD/CAM programs have developed such export functions along with the option of choosing conversion properties, which in fact comes down to the number of triangles. The more triangles, the greater the accuracy of mapping rounded geometries, and thus the higher the accuracy of the solid model and its later physical form.

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