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MODELING OF AGRI-FOOD PRODUCTS ON THE BASIS OF SOLID GEOMETRY WITH EXAMPLES IN AUTODESK 3DS MAX AND FINITE ELEMENT MESH GENERATION

Summary

In order to predict behavior of agri-food products subjected to drying, cooling and heating operations, adequate data on product geometry are required in mathematical models of heat and water transport. Sufficient knowledge about geometry of agri-food products is lacking due to the complexity of their shape. Therefore an original approach consisting in the 3ds Max solid geometry modeling was developed and exemplified for the case of corn and oat kernels. To acquire data on the original product geometry, the approach was supported with image processing and analysis, generation of finite element meshes, and collection of coordinates of mesh nodes. The geometry models of investigated products were developed in the intention of future enhancement of mathematical models and predictions of cereal grain drying and storing processes.
***Key words**: geometry modeling, cereal grain kernels, 3ds Max modeling, FEM mesh generation, software development*

MODELOWANIE BRYŁOWE PRODUKTÓW ROLNO-ŻYWNOŚCIOWYCH Z PRZYKŁADAMI W AUTODESK 3DS MAX I TWORZENIEM SIATEK ELEMENTÓW SKOŃCZONYCH

Streszczenie

Aby prognozować zachowanie produktów rolno-żywnościowych poddawanych operacjom suszenia, chłodzenia i ogrzewania, w matematycznych modelach transportu ciepła i wody są niezbędne dane dotyczące geometrii takich produktów. Brakuje dostatecznej wiedzy o geometrii produktów rolno-żywnościowych z powodu złożoności ich kształtu. Opracowano więc oryginalne podejście do bryłowego modelowania geometrii w środowisku 3ds Max oraz przedstawiono je dla przykładu ziarniaków kukurydzy i owsa. W celu pozyskania danych o geometrii oryginalnych produktów, wsparto to podejście przetwarzaniem i analizą obrazów, generowaniem siatek elementów skończonych oraz pobieraniem współrzędnych węzłów tych siatek. Modele geometrii badanych produktów opracowano z myślą o przyszłym ulepszeniu matematycznych modeli oraz predykcji procesów suszenia i przechowywania ziarna zbóż.
***Słowa kluczowe**: modelowanie geometrii, ziarniaki zbóż, modelowanie w 3ds Max, generowanie siatek MES, tworzenie oprogramowania*

1. Introduction

To simulate transport phenomena occurring in agri-food products, in terms of explaining and predicting behavior of a product subjected to drying, cooling and heating operations, adequate data and procedures are required. For obtaining credible simulation results it is necessary to represent properties of an investigated product with appropriate data in the mathematical models of heat and water transport. Simulation results can be then useful for analyzing and managing industrial food processing systems. The lack of sufficient knowledge about complex geometry of agri-food products is one of the most important obstacles for such computer simulations.

In the literature we can find numerous papers describing systematics of approaches used to model agricultural products [1]. Nowadays computer graphics enables describing shapes of biological objects using parametric equations, boolean operations, representation of boundary curves and surfaces [2]. Modeling of irregular shapes of agricultural solid materials by Bézier curves have been investigated for many years [6, 7]. Another approach is based on the analysis of cross-section images of a product. Geometry data acquired from such analysis were used to model triticale kernels by the Solid Edge software [11], and it was a significant extension of methods applied earlier to model geometry of cereal grain kernels [3, 4, 5]. Similar approach to acquire 3D geometry data from kernel cross-section images was presented in [8, 9], and the authors developed a concept to generate finite element meshes for investigated products, to acquire 3D coordinates of the mesh nodes and to construct models both with the use of the authors' original software and the 3ds Max environment.

The objective of the paper was to implement the concept of modeling of agri-food products on the basis of solid geometry with respect to special features of modeling geometry of corn and oat kernels. A special attention was paid to the oat kernel grid development due to a unique procedure for modeling details. The results will be used in a subsequent paper to improve the mathematical model of temperature and moisture content changes in selected agri-food products by enhancing representation of product geometry and thus to increase accuracy of predictions.

2. Material and methods

In order to create and exemplify models of irregularly-shaped agri-food products, cereal grain kernel samples were selected (corn of the Clarica variety (FAO 280), and oat of the Sławko variety). Procedures used for solid geometry modeling were developed according to concepts described in [9]. The approach was based on taking photographs of slices of the investigated products, processing images of the slices, detecting kernel edges, assembling global finite element mesh for all the slices, and saving 3D coordinates of the mesh nodes. Such approach enabled a preliminary visualization of the investigated products with the use of the developed software. More detailed procedure of modeling and visualizing investigated objects was performed in the 3ds Max environment, and data from image processing and analysis were used with this respect. In case of oat kernels, due to modeling complexity requiring elaboration of adequate procedures, only the 3ds Max software was used and special tools were implemented. The procedures were described step-by-step in Section 3. Results and discussion.

Development of geometry models was undertaken in the paper with the intention of future enhancement of mathematical models of cereal grain drying and storing, to increase accuracy of prediction by more appropriate representation of geometry of investigated objects.

Data for developing all models were acquired by semi-professional photographic equipment and professional industrial scanner. For further processing the Autodesk 3DS MAX 2014 software and the authors' BioProcessSoft information system [10] were used. Detailed steps of modeling are depicted in section 3. Results and discussion.

3. Results and discussion

3.1. Modeling of corn kernels

The process of modeling corn kernels started from the creation of the geosphere (the geodesic sphere) - Fig. 1.

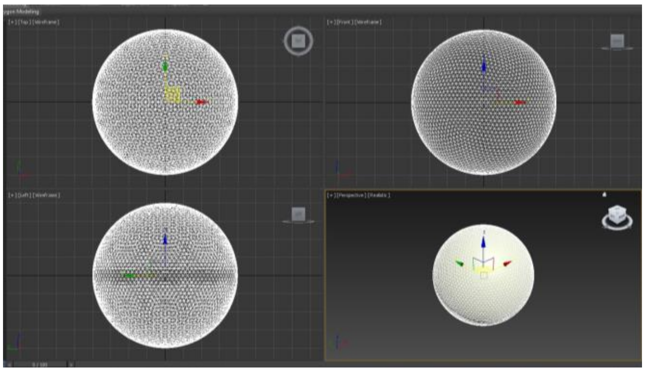

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Fig. 1. GeoSphere
Rys. 1. Geosfera

It is a sphere made up of fewer polygons than its basic form, in addition to its entire surface, the wall (polygons) have the same dimensions, which uses less computer memory for modeling. The grid covering the geodesic sphere is made up of triangles.

After preparing the object, the *Select and Uniform Scale*, and the *Bend* and *Edit Poly* modifiers were applied (Fig. 2).

Modifier action aimed at scaling or zooming in or out the selected dimension of the previously created geodesic sphere. In this case a disproportionate scaling was made, which means that only one of the reduced dimensions was modified. After that, the *Bend* modifier was applied (it enables bending the model along any axis). The modifier is based on four values: *Bend angle, Direction*, *Axis,* and *Limits*. In relation to the corn kernel, the *Bend* was used to extend the model on one side. Next, the *Edit Poly* modifier was used *(Modifiers / Mesh Editing / Edit Poly),* whose main advantage consists in the ability to edit parametric meshes with gear type dedicated to the *Editable Poly* (their subobjects can be modified by selecting the single entity). Corn granuloma was selected in the *Polygon* subobject mode which selects all polygons, taking into account the area that will be subjected to conversion. Firstly the upper part of the kernel was distorted to create a curvature, appropriate to the species. Next step consisted in a modification to give the proper shape to the whole kernel, and the last step - in forming a root. Depending on the currently performed modifications, the mode was changed to the *Vertex* selection (selection of polygon mesh vertices). After selecting the proper area, modifications were made using the *Select and Uniform Scale* and the *Select and Move* tools.

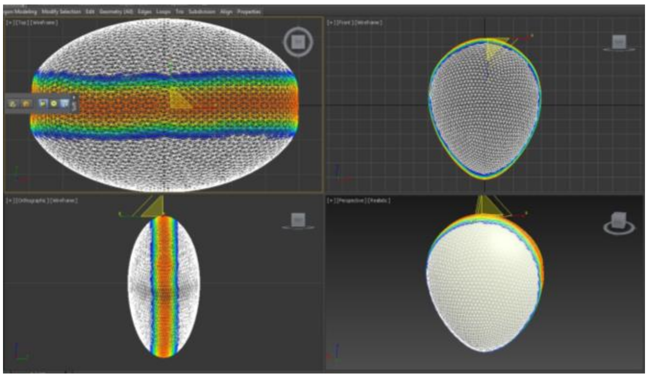

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Fig. 2. Select and Uniform Scale modifier
Rys. 2. Modyfikator Select and Uniform Scale

The last action at this stage of modeling of the caryopsis shape is to give the surface characteristic distortions, using a suitable tool. For this purpose the *Paint Deformation* brush was used which makes the deformation through the translation of vertices in the modeling procedure. This tool is represented by the *pull / push* value determining the direction of the action, and the depth of the deformation. The *Brush Size* parameter defines the radius of the brush, while the *Brush Strength* determines the degree of distortion of vertices. At this stage, with respect to the kernel shape and size, the basic values for the model of the corn kernel complied with the measurements carried out during acquiring data on geometry (Fig. 3).

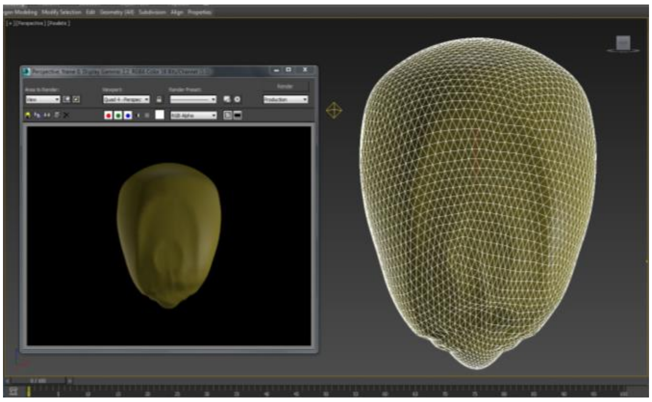

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Fig. 3. Prepared shape and size of the model
Rys. 3. Przygotowany kształt i rozmiar modelu

Before proceeding to the next step considering the imposition of the material, the object mapping should be performed, and it means defining the coordinates of the mapped particles, and on the basis of the maps, preparing the material. After generating maps, the texture was created on the basis of their shape. With the use of the *Elliptical Selection*, the selection of the kernel was clarified. Then, using the *Scale* and *Warp* transformed selection, the pattern was fitted. It was necessary to set the appropriate transparency in order to preview a matching texture map. To align the borders the *Stamp* was utilized, it is important to select the appropriate *brush*, medium *hardness* and *opacity* and *flow*, in this case at ca. 50%. The assigned texture was mapped to the molecules in the *UVWs Edit* window. The *Slate Material Editor* option was selected from the menu, and *standard* material was chosen. For the *Diffuse Color* mapping channel the previously prepared texture was set. It was combined with the object, and next the visibility of the material was indicated in the window (Fig. 4).

As a result of the corn kernel modeling we obtained the fully rendered kernel model. In this process various methods and modifiers were used to accomplish the task, starting from creating a geosphere, through more detail-oriented modifications like scaling and bending the model, or even modifying individual polygons and giving the whole model surface distortions and fractures corresponding to the physical version of the corn kernel. The whole process shows that the most important part of the modeling is to choose appropriate modifiers and also correct values taken from adequate measurements of the physical version of the kernel, to get the best resemblance to the organic version of the specimen.

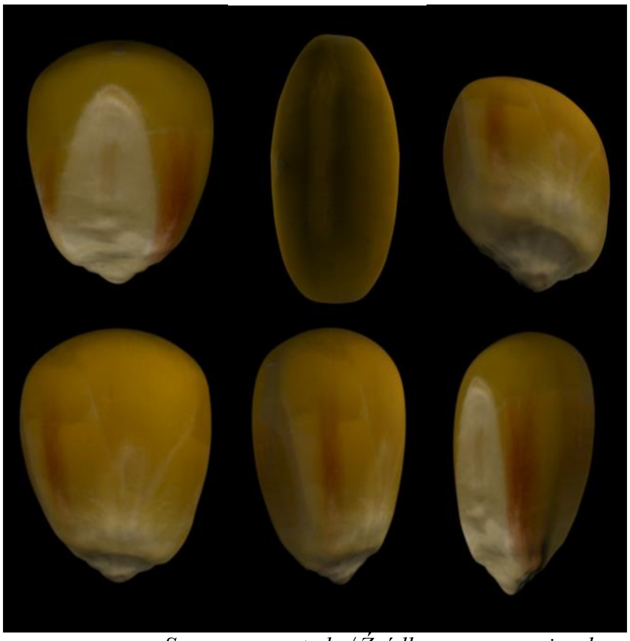

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Fig. 4. Model after texture assignment
Rys. 4.Model po nałożeniu tekstury

3.2. Modeling of oat kernels

The next model was developed for the oat kernel. The process began from creating a cylindrical body *(Chamfer cylinder),* characterized by mild edges. The degree of rounding can be set directly during the process of creating a solid, using the parameter *Fillet* (Fig. 5).

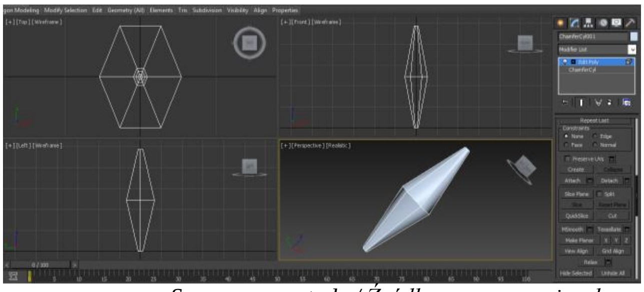

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Fig. 5. Chamfer cylinder
Rys. 5. Chamfer cylinder

In order to eliminate sharp edges of the object, *the Edit Poly* modifier was used. It provides the *Paint Deformation* tool. Mapping of minor irregularities on the surface of the kernel was the next step. The *Noise* modifier was used for this task (Fig. 6).

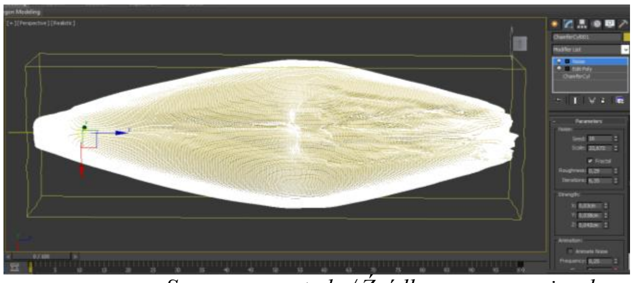

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Fig. 6. Model after applying the *Noise* modifier
Rys. 6. Model po zastosowaniu modyfikatora Noise

The *Noise* modifier is responsible for introducing a random noise and disturbances in the structure of the model, while acting in a direction parallel to the axis set by the user.

Mapping, with the use of the *UVW Unwrap modifier*, on the basis of the exported template of the created texture was the last stage. The texture can be prepared in any image editing program. Generated texture has to be changed in the *UVWs Edit* window. When opening the *Slate Material Editor*, a new *standard* material must be selected. The *Diffuse Color* mapping channel is the place to define previously prepared texture. *Diffuse Color* which scatters light color mapping, allows a user to replace the primary color with a specific texture and gives the opportunity to manipulate the intensity of the color (Fig. 7).

Source: own study / Źródło: opracowanie własne

Fig. 7. Model after texture assigment
Rys. 7. Model po nałożeniu tekstury

Similarly to the corn kernel modeling, we obtained the fully rendered oat kernel model. In this case the process starts at the point of creating chamfered cylindrical body, characterized by mild edges, where the degree of rounding can be set directly in the process of creating a solid. From this point multiple methods were used – including previously used single polygon edition and other tools like deformation and random noise modifier to get more natural look of the model surface. At the end of the process the UVW Unwrap method along with color diffusing were used. It was shown how easy it is to control the intensity of the color and final effect of the surface modifications.

This paper covers both basic and advanced methods of the 3D modeling used in the field of the agri-food representation, and appropriate modifiers were described. They enable recreation of the 3D version of the specimen without much effort and with high efficiency. There are other modifiers that were just mentioned in this paper, they give an opportunity to expand the research and improve resemblance of the model to the original.

4. Conclusions

The methods of modeling of agri-food products on the basis of solid geometry were shown and exemplified by the corn and oat kernel models. Data on investigated product geometry in a form of 3D coordinates of nodes of the finite element mesh were collected for cereal grain kernels by processing and analyzing images of kernel slices. Kernels of corn and oat were used. To support preliminary procedures for data collection, a software package was developed, and essential procedures were performed in the Autodesk 3ds Max environment. The results in a form of corn and oat kernel models fulfilled the requirements of representing geometric shape and dimensions of original products nearly realistically, and thus the models can be used in further research to improve modeling and prediction of drying processes in examined products.

5. References

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