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RESEARCH REGARDING STRESS ANALYSIS OCCURRING IN THE VEGETABLES CUTTING PROCESS

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Abstract: *In the food industry, cutting vegetables and fruit for processing, is rather widely used. This paper presents a method for finite element analysis of the process of cutting vegetables, using the Stress Analysis module of the software INVENTOR. Results obtained from theoretical analysis of resistance at cutting vegetables are compared with results of experimental research made with special equipment in laboratory conditions.*
Keywords: *stress analysis, cutting process, vegetables.*

1. INTRODUCTION

Depending on the nature, structure of food materials can be homogeneous or heterogeneous. In most cases materials of plant origin have a heterogeneous structure (fibrous, lamellar, etc.), being composed of layers with different mechanical characteristics and structures. As a result of heterogeneous structure on the surface of separation between structural elements in the mass of material may occur tension concentrators which can be primers for the development of existing cracks or future creation of cracks that would influence the cutting process. Processing of fruits and vegetables by cutting is more commonly used and is much more important due to large quantities of raw products and considerable energy consumption, of which, however, only a tiny part (0.1 - 0.2%) are actually consumed for overcoming the cohesion forces, the rest is useless or even harmful lost as heat. [1]

Viscoelastic behavior of fruit and vegetables to the mechanical action highlights the dependence of the force, strain and duration of application. Because of the different structure of the tissue studied materials, the viscoelastic behavior of fruit and vegetable tissue is different, experimental measurements on the mechanical level must be achieved through an apparatus and methods for appropriate work. [2]

2. MATERIALS AND METHODS:

Research the influence of structural and functional parameters of the cutting knife on the state of tension that is developing in the structure of the cutting element, were achieved through the Stress Analysis module of the software INVENTOR.

For experimental determination of resistance to cutting, the equipment used was produced by Zwick / Roell and is shown in Figure 1. For acquisition, visualization and analysis of experimental data, the equipment use a specialized software named Test Expert, through which data is stored in the Windows operating system.

An important skill of this equipment is that it saves the result of measurement techniques and access to them immediately. A determination can be defined by two windows: one in which the parameters are presented, and the other by defining how the view of the results (graphs, tables).

The equipment is composed from the frame 1 in which is mounted the drive mechanism of the knife holder, a control panel 2 and a device for vegetables and fruits application 4. The knife 3 is presented in figure 2.

Figure 1: Zwick /Roell stand for cutting resistance determination

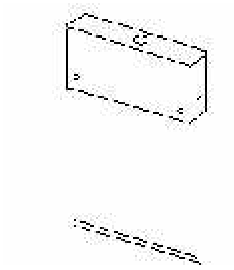


Figure 2: The cutting knife

Experimental determinations were performed on cut carrots with different diameters, thus varying strength of their cutting (table 1).

Table 1: Results of experimental measurements

Probe number	1	2	3
Material	Carrot	Carrot	Carrot
Diameter in cutting area, [mm]	18	21	25
Failure cut depth , [mm]	10	13	17
Cutting depth for maximum strain,[mm]	6.3	8.5	4.5
Maximum cutting strain,[N]	124.0	97.7	82.0

The theoretical research presented in the paper by numerical simulation allow examination of functionality of the knife used for cutting vegetables and fruits and also provides constructive opportunities for optimization of its functional to obtain a correlation between structural and functional parameters.

To examine the state of tension in the knife mass, the resistance induced by the mass subject to cutting, we used finite element method (FEA), which has viewed the tensions that arise at some point in its structure.

Tensions of the mass analysis was performed by importing the blade module of the finite element analysis software specialized INVENTOR 2010, typical applications, generated at a time as a result of interaction between the knife and the mass plant in cutting operation.

Inventor 2010 has implemented a new module technology for finite element analysis (FEA), with which it can make calculations of resistance components and assemblies to verify their behavior in actual operating conditions without building physical prototypes. [3]

3. FINITE ELEMENT ANALYSIS

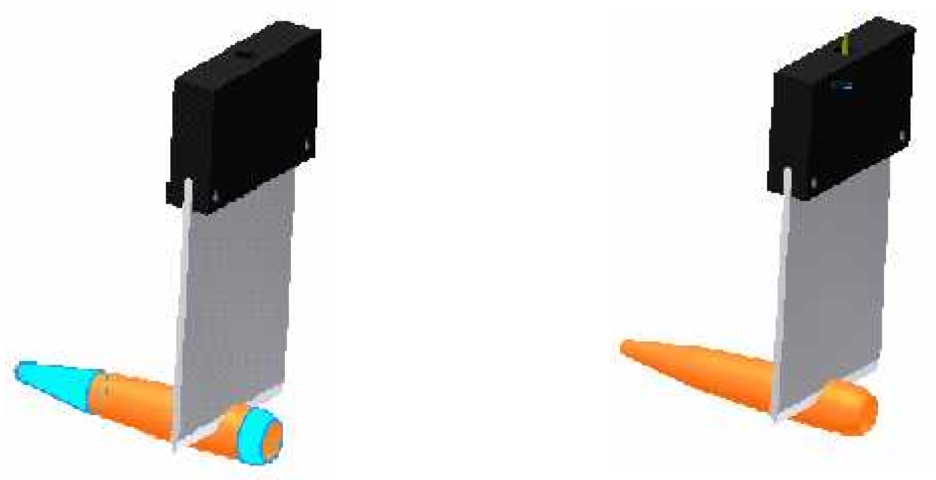
To define the behavior of the cutting blade under the action of external loads using the method of static analysis, conducted in Stress Analysis module of Inventor software, which enables the determination of tensions, strains and forces in the cutting blade structure due to loads resulting from the cutting operation. Loading condition that can be applied in static analysis is characterized by concentrated or distributed external forces imposed by law, applied to the cutter and work surfaces of the blade.

Were performed and analyzed in 3D several sizes of knives in terms of form and sharpening angle value: double-edged knife with sharpening angle of 35 °, single-edged knife with the sharp angle of 35 °, single-edged knife with the sharpening angle of 15 ° and 55 °.

Finite element analysis method involved the following steps:

- *Production model analysis*, was made when exporting 3D knife model in Stress Analysis module. To highlight how the tensions in the knife varies in its fastening system has been applied a force of 124 N, determined experimentally in laboratory conditions using the apparatus Zwick Roell;
- *Meshing the knife structure in finite element*. Initially, the module makes automatically the entire analyzed model, and then in areas where high accuracy of the results is desired would be done manually fine mesh;
- *Verification of finite element model and running analysis*. [3]

For body work used to do the operation of cutting vegetables was chosen structural model of a 3 mm thick blade, sharpened on both sides, with the sharpening angle of 35 °, perpendicular (fig. 3).



a. *b.*

Figure 3: 3D system representation of the knife model:
a. carrot with mobility canceled; b. force applied to the knife

To fully define the cutting process and to achieve results, the material used in the cutting process was a carrot, whose mobility was abolished (fig. 3, a). The force which acts on the knife was applied at the top (fig. 3, b). Figure 4 is presented the stress distribution of the knife obtained by running analysis. Maximum tension generated in the knife as a result of interaction with the plant material is 23.26 MPa, resulting from the application of a force of 124 N.

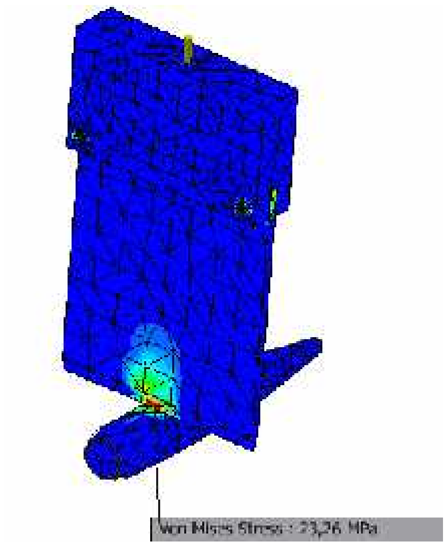


Figure 4: Representation of the mesh on a double-edged knife with sharpening angle of 35 °

4. RESULTS AND DISCUSSION

Initial, processing stage results is done by software; it generates for each analysis a full report in word format.

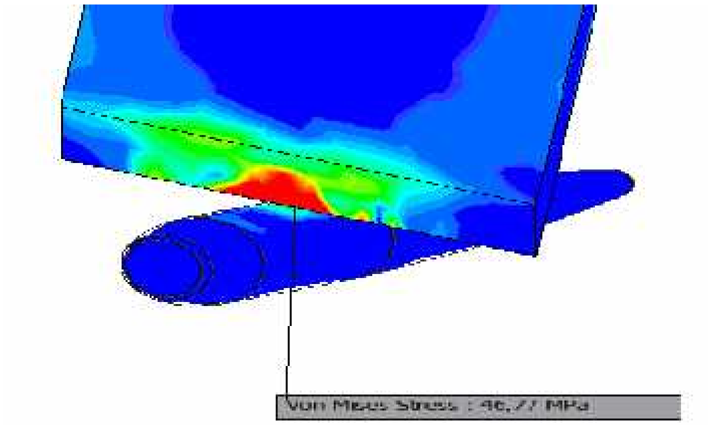


Figure 5: Representation of tensions in a single-edged knife with sharpening angle of 15 °

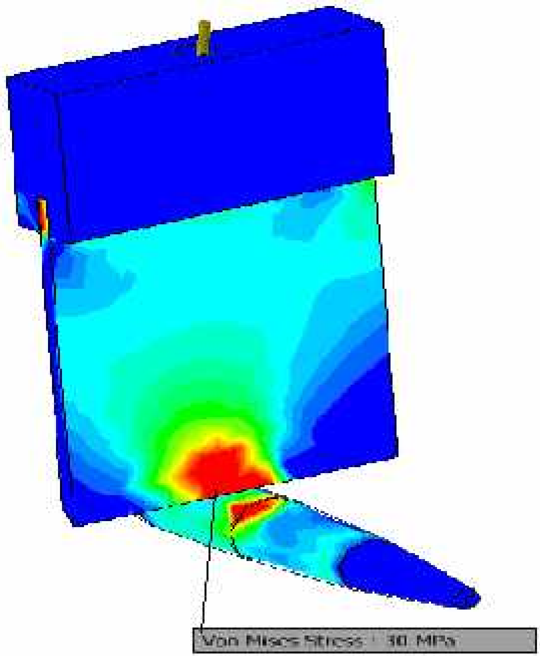


Figure 6: Representation of tensions in a single-edged knife with sharpening angle of 35 °

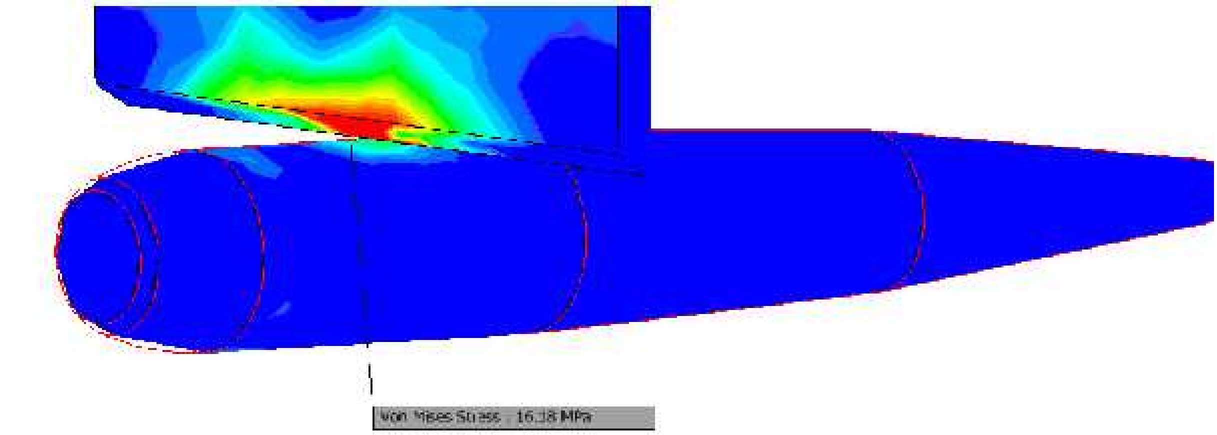


Figure 7: Representation of tensions in a single-edged knife with sharpening angle of 55 °

5. CONCLUSIONS

Analyzing the reports made by Stress Analysis software on the maximum stress occurring in studied knives, is found that the greatest tensions arise at low values of the angle of sharpening:

- for single-edged knife with sharpening angle of 15 ° was obtained a maximum stress of 46.77 MPa.
- for double-edged knife with sharpening angle of 35 °, the maximum stress was 23.26 MPa.
- for single-edged knife with sharpening angle of 35 ° was obtained a maximum stress of 30 MPa.
- for single-edged knife with sharpening angle of 55 ° maximum stress obtained was 16.18 MPa.

Analysis of the results allowed highlighting the geometric influence of knife, whether it is single or double edged. When the knives have the same sharpening angle (35 °), lower values of tension were obtained on a double-edged knife (σ = 23.26 MPa) compared with the case of a single-edged knife (σ = 30 MPa).

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