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AIRFLOW SIMULATION IN DIFFERENT TYPES OF STORAGE CELLS

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Abstract: *This paper presents the importance of storage cells construction in maintaining a constant temperature for products placed at different heights. Also of great interest is the speed of the airflow that enters in contact with fruits or vegetables because this factor can accelerate the products dehydration. To have a general image, for this simulation were chosen three different types of cells, which are most often found in warehouses.*

Key words: *airflow, simulation, warehouse.*

1. Introduction

Warehouses for fruits and vegetables that exist worldwide are very different from one country to another depending on the climatic conditions, economic possibilities, the production organization etc. The main classification criteria for warehouses are:

- According to the storing conditions in the depositing space: without automatic adjustment systems for climatic parameters and with automatic adjustment system for climatic parameters;
- According to the constructive type: mono-pavilions and multi-pavilions;
- According to the degree of provision with machinery and technical equipments for climatic control, conditioning etc.: simple and improvised, which do not have any equipment and also, are not constructions which are adequate for storing in conformity to technological prerequisites; specialized warehouses without equipments; modern warehouses which have an adequate construction and all the installations and equipments necessary;
- According to the thermal solution used for the warehouse cells climatic control: with centralized installation; with individual installation for each cell;
- According to the automating degree: without automatic installation; with installation which assures the determination of the parameters which are involved in the storing process; with installations which assure the monitoring, control and automatic adjustment of the storing parameters [1], [4].

Choosing the refrigeration and freezing method depends on the products' degree of perishability, those with high perish degree must be cooled very quickly. From the point of view of the perishability degree, fruits and vegetables are divided into the following groups:

- extremely perishable products: blueberries, strawberries, blackberries raspberries, mulberries, fresh figs, spinach, sorrel, cress;
- very perishable products: apricots, cherries, quinces, early apples, early pears, peaches, plums, grapes with soft skin, green onions, mushrooms, Cornichon cucumbers,

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greenmbeans, peas green beans, carrots with celery, parsley leaves, early leeks, lettuce, asparagus, beetroot, green celery, green garlic, early cabbage;

- perishable products: summer pears, grapes, olives, artichokes, peppers, Okra, beans, cauliflower, green beans, peas, carrots, cantaloupe, tomatoes, cabbage, Brussels sprouts, eggplant, leeks;
- relatively resistant: autumn apples, winter pears, chestnuts, potatoes, onions, horseradish, parsnip roots, beetroot, garlic head [2].

The simulation was made in SolidWorks using SolidWorks Flow Simulation tool. SolidWorks offers a suite of simulation packages that enable you to set up virtual real-world environments so you can test your product designs before manufacture. Test against a broad range of parameters throughout the design process-like durability, static and dynamic response, motion of assembly, heat transfer, and fluid dynamics to evaluate product performance and make decisions to improve quality and safety. Simulation lowers cost and speeds time to market by reducing the number of physical prototypes you need before going into production. SolidWorks Simulation helps designers and engineers to innovate, testing and developing new concepts with greater insights.

SolidWorks Flow Simulation takes the complexity out of computational fluid dynamics. You can quickly and easily simulate fluid flow, heat transfer, and fluid forces that are critical to the success of your design. Simulate liquid and gas flow in real world conditions, run "what if" scenarios, and quickly analyze the effects of fluid flow, heat transfer, and related forces on immersed or surrounding components. Design variations can be compared to make better decisions, resulting in products with superior performance. Specific modules simplify the specialized analysis of HVAC and electronic cooling [5].

2. Material and Method

The simulation was made for three different types of store cells, which are representative for warehouses existing in Romania. The cell dimensions and the store box dimensions are the ones that were measured at the National Institute of Research and Development for Potato and Sugar Beet Braşov. To draw pertinent conclusions these dimensions were used in all simulations.

For the store cell the dimensions are: length = 5000 mm, width = 5000 mm, height = 5500 mm and for the store box: length = 1000 mm, width = 800 mm, height = 1000 mm. The sketch was made with these dimensions so a real model of the store cell was created.

In the simulations, for the airflow speed and temperature, the potatoes mass temperature and the inside cell temperature and humidity were used, the values which were measured in the warehouses of the National Institute of Research and Development for Potato and Sugar Beet Braşov. So, the airflow speed was 1 m/s; airflow temperature - 277 ^{o}K; potato mass temperature - 283 ^{o}K; inside cell temperature - 278 ^{o}K; inside cell humidity - 90% [3].

The first simulation was made with a store cell which exists at the National Institute of Research and Development for Potato and Sugar Beet Braşov (Figure 1).

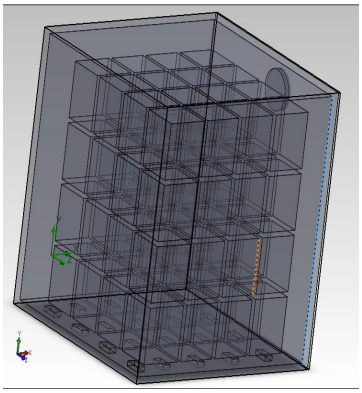


Fig. 1. *Sketch of the first type storage cell*

With this type of store cell, the conditioned fresh air is introduced through the perforated floor with a constant speed and then is evacuated trough a circular hole in one of the lateral walls. A part of this air is recirculated and mixed with the outside air before entering the conditioning installation for assuring lower energy consumption when conditioning the air.

The second simulation was made with a store cell used in warehouses for products which produce a significant quantity of heat. With this cell, the fresh conditioned air is introduced through the top side by a circular ventilator and the existing air is evacuated through holes in two opposite walls as it can be seen in Figure 2.

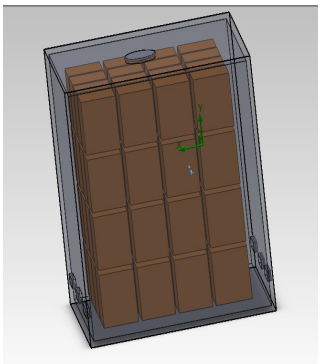


Fig. 2. *Sketch of the second type storage cell*

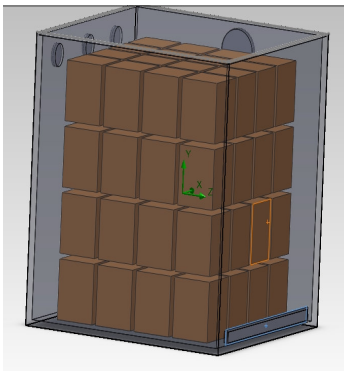


Fig. 3. *Sketch of the third type storage cell*

The third simulation was made with a cell (Figure 3) in which the fresh conditioned air is introduced trough a hole placed in the lower part of a wall and the existing air is evacuated through three holes placed in the upper side of the opposite wall.

After these three models were design of the material of the solids and the climatic parameters were defined. So the first step was to create a new material which has the potato's physical property (Figure 4).

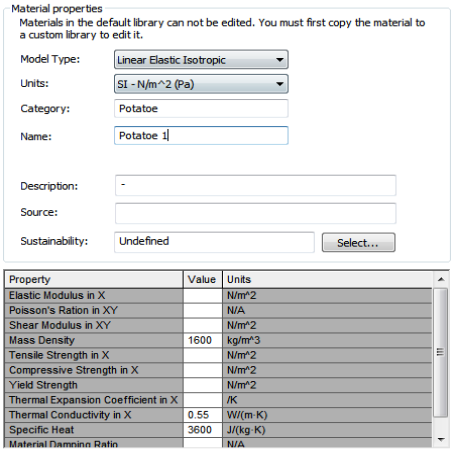


Fig. 4. *New material properties defining window*

Secondly the parameters of the cell inside fluid (air) such as temperature, humidity, pressure, turbulence intensity, turbulence length and the solid (potato) temperature were defined (Figure 5).

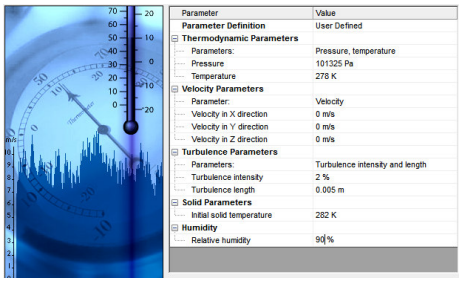


Fig. 5. *Inside cell parameters definition*

Thirdly the airflow parameters like: speed, pressure, temperature, humidity, humidity dew point were defined (Figure 6).

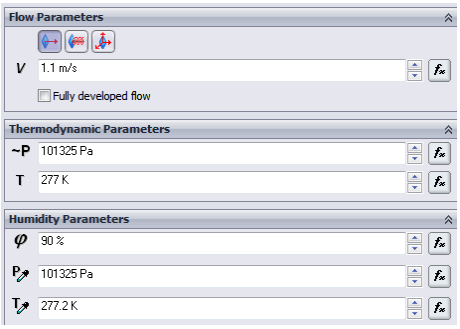


Fig. 6. *Airflow parameters definition*

With these parameters defined the simulations were started. For every model three simulations were performed, at 1 second physical time, at 5 seconds physical time and when the solid reached the fluid temperature.

3. Results and Discussions

SolidWorks creates automatically a mesh for the sketch and begins computing according to the mesh refinement and the physical time. So, for the first type of cell the program creates a mesh with 43903 fluid cells, 21208 solid cells and 80923 partial cells (Figure 7). For a simulation of 5 seconds physical time 770 iterations were needed, which were done in 1 hour and 32 minutes with a PC which has an Intel Core I5 2.4 GHz processor.

For 1 second physical time the simulations are presented in Figures 8a, 9a and 10a for

Parameter	Value
Status	Solver is finished.
Fluid cells	43903
Solid cells	21208
Partial cells	80923
Iterations	770
Last iteration finished	14:23:20
CPU time per last iteration	00:00:06
Travels	
Iterations per 1 travel	264
Cpu time	1 : 32 : 27

Fig. 7. *Information about the solver*

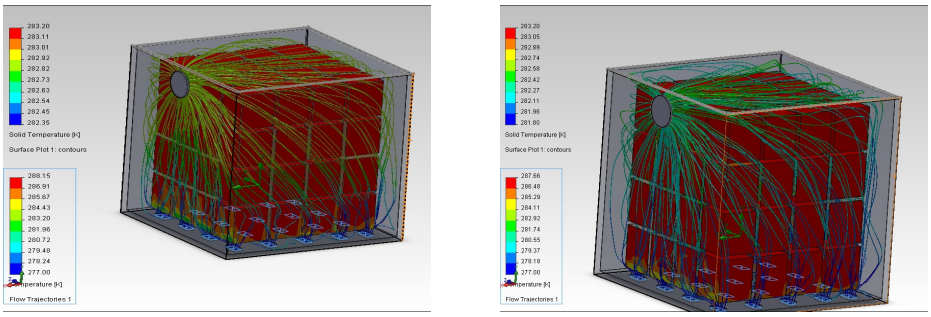
the three types of store cells. In these figures the airflow temperature variation and the solid temperature variation are presented.

For 5 seconds physical time the simulations are presented in Figures 8b, 9b and 10b also for the same three types of store cells. As for 1 second physical time the significance of the figures is the same.

Finally in Figures 11, 12 and 13 are presented the cells after the solids surface reached the airflow temperature and the inside cell climatic parameters are the same as the airflow parameters.

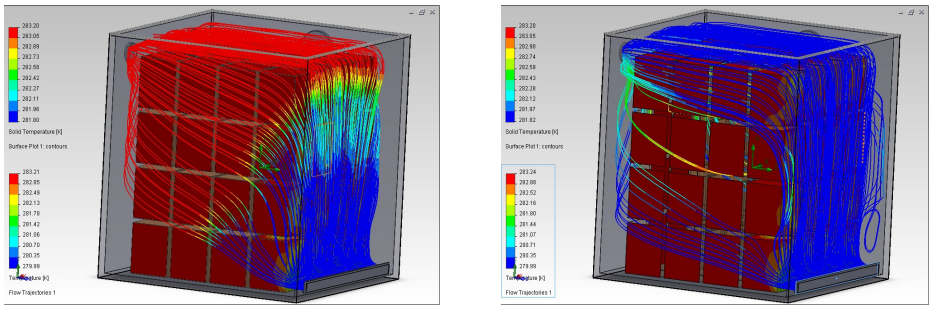
As expected, the most inefficient system is the one in which fresh air is introduced through the lower side of a wall and evacuated through the upper side of the opposite wall. This type of construction is unable to assure a proper airflow to store boxes situated in the lower part of the stack which is opposite to the air inlet.

This type of construction could be used right after harvest when it is important to dry products. So by rotating the boxes the whole mass of products can be dried.



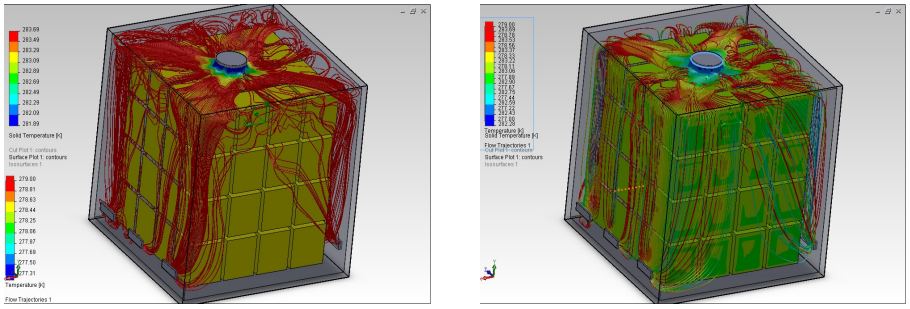
a) b)

Fig. 8. *Simulation results for the first type of storage cell*



a) b)

Fig. 9. *Simulation results for the second type of storage cell*



a) b)

Fig. 10. *Simulation results for the third type of storage cell*

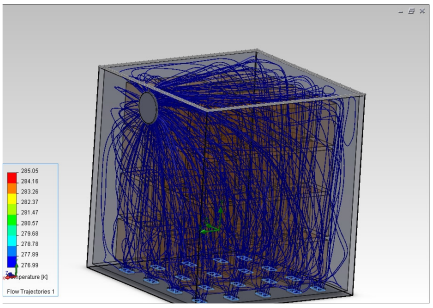


Fig. 11. *First type of storage cell*

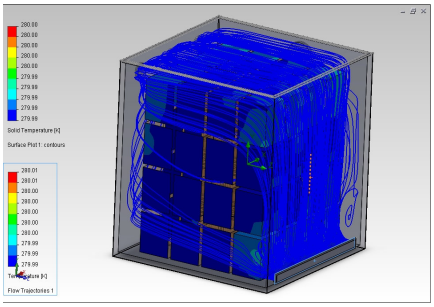


Fig. 12. *Second type of storage cell*

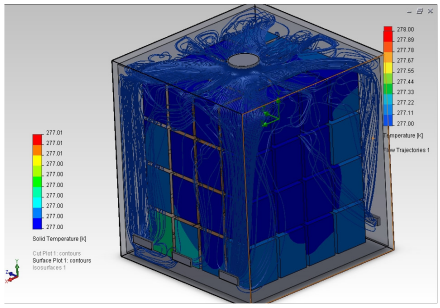


Fig. 13. *Third type of storage cell*

4. Conclusions

1. Nowadays due to modern simulation software, it is recommended that before making a decision about a constructive design to perform a simulation which can indicate how the airflow would manifest inside the warehouse cell.

2. Used for short periods of time the first and the third type of constructive design

offers a good solution and can assure a homogenous air mixture.

3. In warm climates where climatic installations work for long periods of time the constructive design becomes less important because, as it results from these simulations, after a certain time period the general effect of the airflow over the products is the same. So, a greater importance must be given to the climatic factors' precise control.

Acknowledgements

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