



SIMULATING THE OPERATION OF THE FLAX AND HEMP RETTING AND DRYING EQUIPMENT USING THE SIMULINK/MATLAB SOFTWARE

Liliana INDRIE, Sabina GHERGHEL, Ioan ALMĂŞAN

University of Oradea, e-mail: lindrie@yahoo.com

Abstract – One of the viable solutions of applying modern technologies to the melting and drying of flax and hemp is the use of geothermal water for the preparation of the hot water used in the melting tanks or for the preparation of the hot air used for drying. In order to check the correctness and the functionality of the model that we have created in Excel, this paper presents the simulation of the operation of the flax and hemp retting and drying center, in winter conditions, for one day within the biological phase.

Keywords: simulation, Matlab, geothermal water, hemp, flax.

1. INTRODUCTION

The hydro-geothermal perimeter of Oradea is part of the Aleşd - Oradea - Felix hydro-geothermal system, which is, in turn, part of the Mesozoic regional hydro-structure of the northern part of the Pădurea Craiului Mountains. The aquifer covers the Western terminal area of the northern Apuseni Mountains, a region which is included in the sunken foundation of the Pannonian Depression, as well as the Western half of the Vad - Borod Neogene depression. In the regional context, the region of Oradea lies in the South-Eastern part of the Carpathian-Pannonian region, at the Eastern limit of the Pannonian Depression.

Thenceforward, making reference only to the well no. 1720 for which we are designing the application used for the primary processing of Liberian fibres, we can see that the **maximum flow** which can be driven back into the well in an artesian regime, namely without installing a depth pump or at the head of the well, **is of 30 l/s** for the free forcing back into the atmosphere. The well is placed at the Western end of the perimeter of Oradea, it produces geothermal water with a **temperature of 76°C**, from a depth of 1800 - 1900 m, out of Cretaceous age formations.

The mathematical model has been developed in Excel and it has certain advantages, emphasized by its running under different conditions, but for the practical analysis of the global action of the center, certain limits of the Excel programming environment are also underlined.

For instance, the described model reflects a perfect automation of the system; that is, we can say that a variation of the environmental conditions will lead to

an immediate variation of the geothermal water consumption. In real equipments, delays appear based on the chosen automation type. In order to be able to analyze and predict the real action, we need to develop a model in a program which allows the study of non-linear phenomena as well. We have chosen as a working environment the MATLAB [3] software, the center model being developed within the Simulink software package. The basis for the development of the model in Simulink is the mathematical model written in Excel [2]. Unlike Excel, where the solving of the differential equations is difficult to do, if not even impossible, Simulink can simulate even the non-linear action of the constituting elements of the processing center.

The model that we have created in Simulink for the technical crops processing center is also a linear model, that is, a model having a perfect automation. Working in the Simulink environment allows nevertheless a subsequent development of a non-linear extension which reflects the influence of the delays caused by the response of the real regulators, of the tap driving elements, of the non-linearity of the heat exchange, etc. This field can be one of the directions that this thesis can open for future studies. Moreover, the creation in the first stage of a linear system similar to the mathematical model previously developed can help us confirm the correctness of the created sub-models, by comparing the results of the partial simulations to the results of the different series of lines in Excel. Finally, the curves that we will obtain using the linear model in Simulink/MATLAB, in the **scope** blocks, will have to be similar to the series of curves obtained using the Excel software, which will confirm the correctness of the model in Simulink.

As principles for the construction of the model in Simulink [1] we can mention: the storage of the physical data of the designed elements (geometrical dimensions, layout, materials, number of pieces, etc.) of the designing phase. These can be changed if we want to obtain the simulation of the action of a similar model which is slightly different from the designed one; the preservation of the capacity of the software to decide the size of the accepted batches; the modeling of each heat exchanger in part; perfect and immediate automation; for running the simulation, the same sinusoidal variations are used for the environmental

parameters; for the subsequent development, the possibility of integrating a subsystem which contains the automation of the system should exist.

2. PREPARATION OF PAPERS DESIGNING THE EQUIPMENT FOR THE MELTING AND DRYING OF FLAX AND HEMP USING GEOTHERMAL WATER

The primary processing of the harvested stalks supposes two technical applications (technological processes) which are different from each other, namely the **melting (M)** of the stalks, respectively their **drying (D)**. These technological processes are common to both plants (to flax, respectively to hemp), and they do not differ very much, based on the type of the processed plant; nevertheless there are differences between the parameters of a process applied to a plant and the parameters of the same process applied to the other plant, differences which are caused by the different sizes of the stalks and by their slightly different chemical composition. Thus, we can distinguish four different technical applications: **flax melting (FM)**, **hemp melting (HM)**, **flax drying (FD)** and **hemp drying (HD)**.

After the calculations [4], the multitude of potential variants of the processing centre was reduced to only a few, starting from the existing thermal power potential and the energetic consumption particularities of the used technologies, namely the anaerobic melting using hot water in open tanks, respectively the drying in a multi-cellular tunnel with intermediary heating processes.

We have reached two variants, the first one – **using four tanks** – being undersized with regard to the optimal functioning conditions, and the other one – **using five tanks** – being sized only with a small margin under the necessary, for the optimal conditions, and clearly oversized for unfavorable functioning conditions, following that in such cases it should function to a smaller capacity than the nominal one.

The constructive variant of the flax and hemp processing centre will look according to the diagram in **fig. 1**. For drying, the solution enforced by the technological process particularities is a multicellular drying tunnel, in each cell a fraction of the total humidity will be eliminated; heating the drying air is achieved best with the help of heat exchangers with extended surfaces (radiators), one for each cell. We have nine drying cells, and a last cell, the tenth will be a conditioning cell in which the material (stalks) are sprinkled with a fine fog if they were dried more than needed, so if their humidity is less than 12%.

A drying cycle lasts four days from filling the tanks up to finishing the melting process. In between melting two lots we need one whole day for emptying the tanks, cleaning and refilling them, after which the process can be resumed with a new lot. In parallel, this

period of time can be used for doing the maintenance works at the drying tunnel (cleaning, dusting the filters, lubricating the bearings, etc).

This means that once every four days, in the fifth day, the water from the well is not necessary and the output can be reduced to minimum (zero).

On the other hand, the well can be left working in the fifth day too at full capacity and the water produced can be stored in a storage reservoir and it can be used later when the need of thermal power exceeds the well's possibilities, offering an extra output according to necessities. For designing the structure and the component elements we started from the available quantity of geothermal water that is an output of 30 l/s, which can reach 37.5 l/s when using a storage tank which is supplied during the cleaning period of the tanks between the two melting cycles and it is emptied during the melting-drying cycle.

In order to insure a higher degree of flexibility between the instant charge values of the two productive processes (melting-drying) a second storage tank (buffer) should be designed for gathering the geothermal water coming from the drying process, before using it in the melting process.

In this way, the geothermal water coming from the drying tunnel which reaches the exchangers with casing pipes, where it heats this secondary agent (water supply). The secondary agent is then sent back to the grid exchangers on the bottom of the melting tanks, where it heats the melting water, keeping an average temperature of 36°C and making for the heat losses that show up during the mechanisms mentioned before.

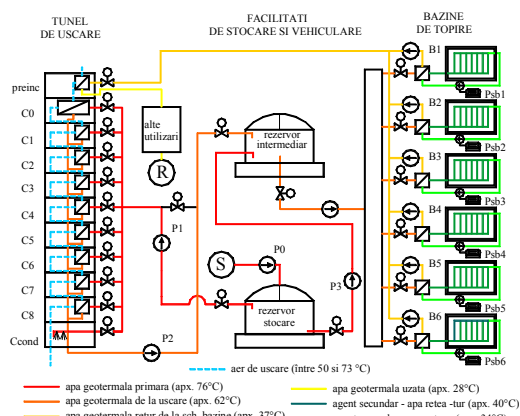


Figure 1. Functioning diagram of the flax and hemp processing centre

We designed four pumps (P0 – direct link from the well to the collector if the artesian output is too small and we want to increase it, P1 – which extract the geothermal water from the storage tank and sends it to the drying cells radiators, P2 – on the return from the

drying tunnel collector to the buffer tank (geothermal water collector for melting) and P3 – pump for shortening on the drying tunnel, from the storage tank to the buffer tank), in order to obtain the same pressure at the entrance of the three geothermal water outputs to the collector. If there is a high enough pressure in the collector, then pumps Pb1 ... Pb6 are not necessary, only those for circulating the secondary agent Psb1 ... Psb6 being compulsory.

3. LIBRARY CONTAINING USER-CREATED MYLIB.MDL BLOCKS

In order to be able to rigorously model the heat exchange which appears in different exchangers within the system, we have created different blocks and grouped them in a user library, which has the same appearance as the one in Figure 2

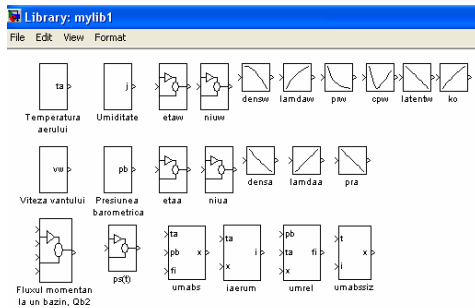


Figure 2. Library of mylib.mdl user-blocks

The library contains the user blocks for the calculation of water and air properties, which are mainly interpolation functions, like the ones written in Excel. For example, in Figure 3., the function behind such a block is presented. Unlike functions written in Excel, these block-functions do not return constant values outside the 0 ... 90 °C interval, but they do an extrapolation. Even the interpolation takes into account the rate of the whole curve and it is not directly linear, hence the appearance of a slight difference as opposed to the corresponding functions in Excel. In Figure 4., the sinusoidal source block which supplies the variable temperature of the air is presented, while the blocks for humidity and wind speed are written in a similar manner.

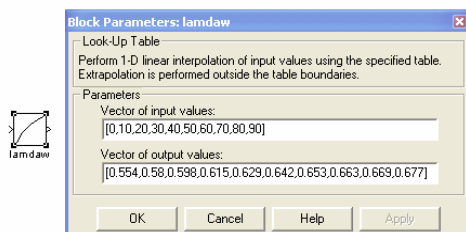


Figure 3. Structure of an interpolation block

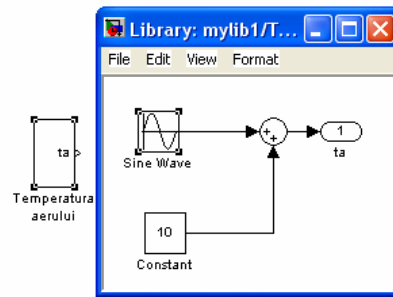


Figure 4. Structure of a sinusoidal source block

The library also contains blocks for the calculation of the saturation pressure based on temperature. The pressure is calculated in several steps, just like the user functions in Excel, that is the reason why this block is, in turn, one which contains several subsystems. The library also contains complex blocks for the calculation of absolute humidity, knowing the relative humidity value and the other way round, blocks for the calculation of the enthalpy using absolute humidity and the other way round, as well as a block for the calculation of losses in a tank, which is a complex block, as can be seen in Figure 5, containing as subsystems the flows lost through evaporation, convection, radiation and conduction. This block appears several times within the model and it is also necessary for an eventual subsequent development of the system by adding an automation system. The library can be subsequently extended, along with the extension of the model.

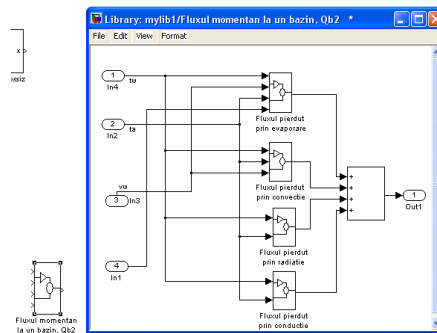


Figure 5. User block for the calculation of the momentary flow in a tank

4. RUNNING THE SIMULATION IN THE WINTER SEASON AND RESULTS PRESENTATION

In order to check the correctness and the functionality of the model, we have run a simulation of its operation in winter conditions, for one day within the biological phase. The starting data are specific of the *winter* season, the suggested charges are those of the designing phase, but, of course, any batch sizes can be suggested, as the decisional block will redirect a part of the suggested quantities to the next cycle, if

necessary. The suggested quantities of 103,968 kg, both for retting and for drying, are integrally accepted by the decisional block of the software, the retting constituting the priority of the technological process. In the display boxes (see figure 6), the software shows the quantities which were accepted and redirected for retting (the red displays – 103,968 and 0) and for drying (the green displays – 103,968 and 0), and the number of tanks that can be used simultaneously during that season (the short red display – $zacc = 4$ tanks).

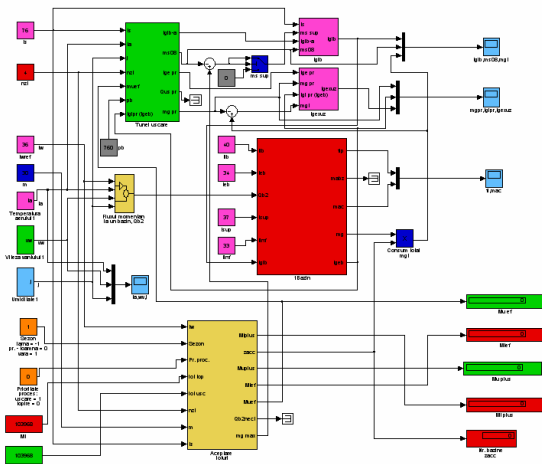


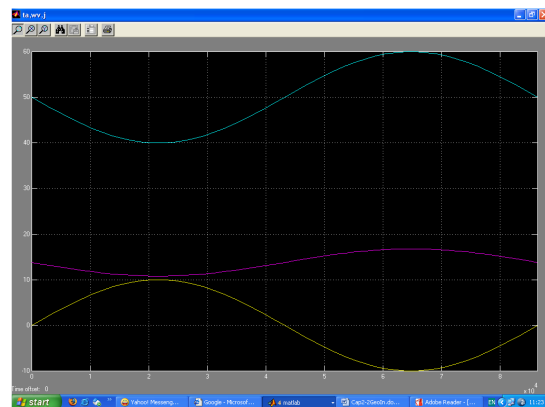
Figure 6. The Primary Structure of the Processing Center Model

As we can notice in the figure, there is a series of source blocks, which represent the input sizes: environmental parameters (air temperature and humidity, wind speed), geothermal water flow and temperature at the well, the imposed temperature for the retting water in the tanks, the number of days of a production cycle, the suggested size for the batches in the current cycles, as well as information on the season and on the priority of the drying process as opposed to the retting process (or the other way round), when resources are not enough for both (see the Excel mathematical model).

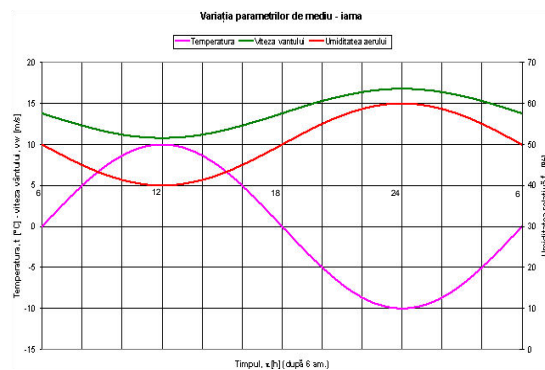
The model has three large blocks: the decisional block for the batches which are to be accepted in the current cycle (*Batch acceptance*), a block for modeling the phenomena which occur during the retting process in a tank (*ITank*), respectively a block for modeling the phenomena which occur in the drying tunnel (*Drying tunnel*). The three large subsystems are interrelated. The decisional block sends the other two blocks data on the size of the accepted batches, the respective number of tanks which work simultaneously, and the *Drying tunnel* block provides the retting block with the input temperature of the geothermal water at the level of the covered pipe exchangers. The other way round, the *ITank* block sends the drying block the value of the input temperature of the geothermal water at the

level of the air preheater. The output sizes of these blocks are emphasized using some display blocks – for the fixed sizes, such as the values accepted for the batches and those redirected to the next cycle – respectively some scope-type blocks for the graphical presentation of the time variations of the different interest sizes, consumptions, temperatures, etc.

We have fixed the simulation period to one 1 day = 24 h = 86,400 seconds. The obtained results were graphically represented using four **scope** blocks, as follows: in figure 7, the variations of the environmental parameters are given (air temperature and humidity and wind speed) for a typical winter day (7a Simulink, 7 b Excel); in figure 8, the variations of geothermal water consumption at the retting tanks and at the drying tunnel are grouped, as well as the output temperature at the drying tunnel radiators; in figure 9, the diagrams of the geothermal water consumption at the preheater are given, as well as the output temperature of this water and the temperature of the used water which leaves the center; and in figure 10, the deviation angle of the blades and the secondary agent flow are represented.



a) Simulink

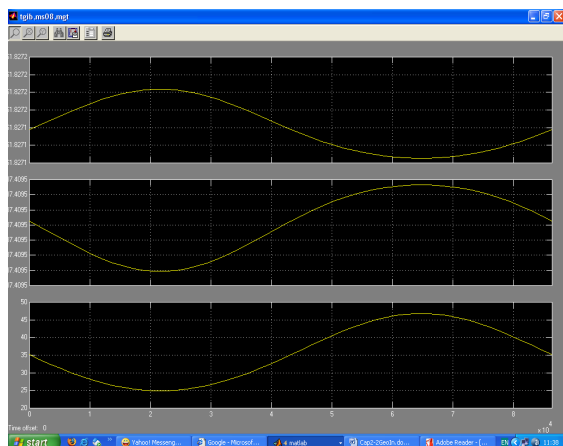


b) Excel

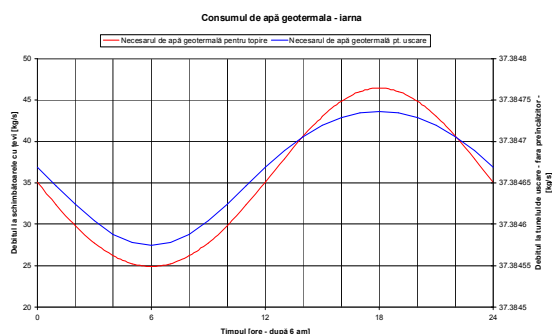
Figure 7. Results of the Running for the Variation of the Environmental Parameters

We have chosen that the input should be of a vector type, so that the three curves have the same y axis – that is, the same scale, even if the measurement units

are different ($^{\circ}\text{C}$ – for temperature, m/s – for wind speed and $\%$ - for relative humidity), and they are represented in different colors. The **scope** block does not allow multiple axes for a vector size, so we preferred that the other **scope** blocks have several scalar inputs, so that we could fix the scale for each size in part. Each size will be represented using its own y axis, the x axis being the only common one.



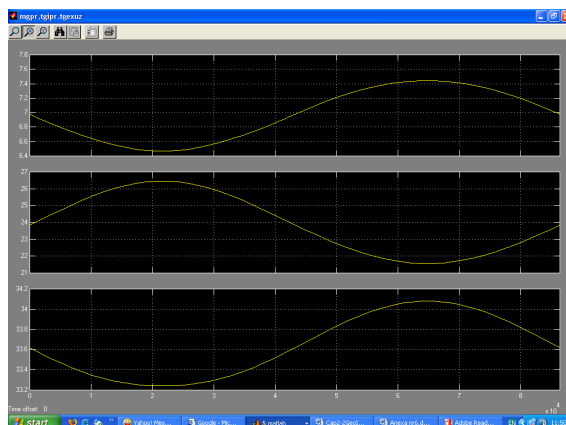
a) Simulink



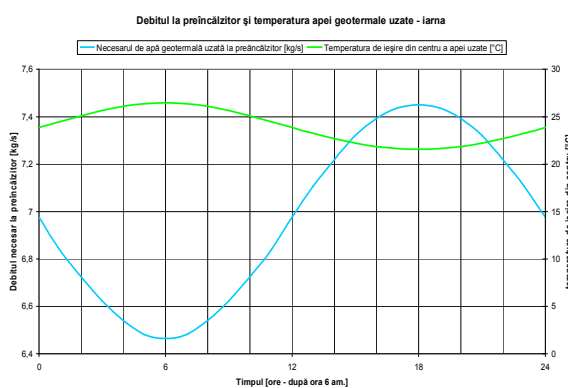
b. Excel

Figure 8. Results of the Running for the Variation of the Consumptions during Retting and Drying

In figure 8, the three sizes, a temperature and two flows are all represented in yellow, but in three different fields. The *auto scale* option – for the automatic fixing of the scale on the y axis – of the **scope** block makes it look like we have the same curve for the flows, but if we read the numerical indications on the y axes, we will see that the curves are, in fact, different. If the two flows had been represented at the same scale, then the consumption curve during the drying process would have practically been a straight-line, the variations being very small.



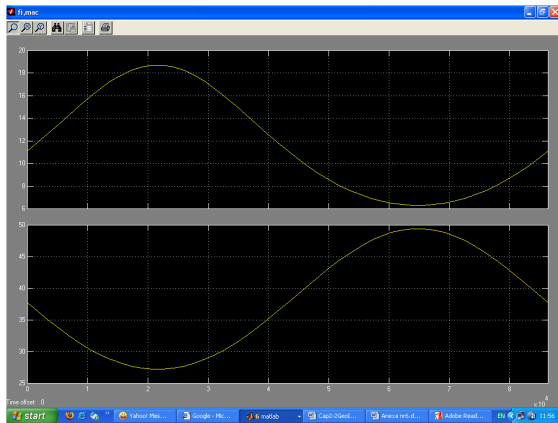
a) Simulink



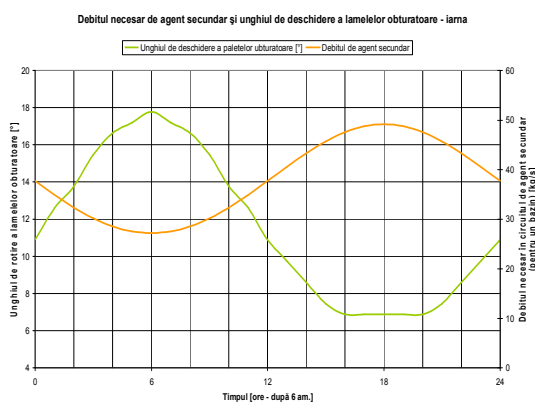
b. Excel

Figure 9. Results of the Running for the Variation of the Consumption at the Preheater and of the Output Temperature of the Geothermal Water in the Preheater and the Center

The two curves are identical with the ones in Excel (the consumption's variation for the pre-heater and the egress temperature of geothermal water from the centre), the third curve (the egress temperature of geothermal water from the pre-heater) is not plotted. However, in figure 10 we can see that as compared to the curves obtained in the Excel software, the curves obtained following simulation in Simulink/MATLAB are more even, they do not show discontinuous variations of the gradient, because Simulink is dedicated to simulation and has a much more efficient internal solver than the user functions written in Visual Basic for Excel (the convergence is finer). In order to obtain the same degree of evenness of the curves, the iteration rate of the functions in Excel should be even smaller, and the recalculation time of the worksheet would be considerably higher.



a) Simulink



b. Excel

Figure 10. Results of the Running for the Variation of the Secondary Agent Flow and of the Shutter Blades' Rotation Angle

4. CONCLUSIONS

In conclusion, the simulation of the flax and hemp processing center (for the *winter* season) has lead us to the same results as the mathematical model developed in Excel, which confirms the correctness of the

model developed in Simulink/MATLAB. Moreover, the curves obtained following simulation in Simulink are more precise and more even than the ones obtained using the model written in Visual Basic for Excel. The simulation (for permanent, non-transitory conditions) in MATLAB lasts for 2 or 3 seconds, but in Excel, the recalculation of the entire worksheet may last for more than 30 seconds, which is a net advantage to the simulation in MATLAB.

Which is even more advantageous for the model in MATLAB is the fact that it can subsequently adapt to different developments by writing new sub-models, including a block-sub-model for the description of the non stationary processes, based on the solutions chosen for the automation of the center. In Excel, such a module is difficult to write and even more difficult to run; the recalculation of the sheet can reach very high time intervals, while in Simulink/MATLAB it will remain at values of the order of seconds.

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