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# OPTIMIZATION OF MIXED-FLOW GRAIN DRYERS BASED ON THERMAL ANALYSIS

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**Abstract**

*The drying process is the key element of the technology for secure storage of the harvested grain. Economic significance is appreciable and it affects the effectiveness of many other sectors (e.g. food industry, animal production). However, grain-drying is a flammable technological process. The secure warehousing and the quality of the harvested grain and feeds are important segment of the environmental protection; hence, the quality of the feeds significantly affects the excellence of the animal origin products. The improper drying-process leads to troubles during the warehousing (microbes, dust). But how do we know that the drying-technology is working on an optimal level? This paper introduces a novel measurement method which gives detailed overview of the drying process. There are 15-20 main type of grain driers in Hungary, this paper gives an overview of thermal analysis of the most popular types using a measurement system based on a Hungarian patent. Based on the data from the measurement system precision drying – a new level of efficient drying – will be introduced.*

**Keywords:** precision drying, grain dryer, optimization, thermal analysis, Videokontroll

## 1. INTRODUCTION

A grain-dryer is built for the next 20-30 years. What are the market needs: reduced costs, efficient operation and control, besides better monitoring of temperature and speed parameters, and one of the most important requirement is the fire prevention. The grain dryer is an expensive investment; therefore, the owners want to establish the most efficient technology. It is worth to use the most innovative devices and solutions to achieve the optimal drying-process. Essential requirement is the optimal moisture distraction in the dryer and the simple fine tuning possibilities during the installation. The modern grain dryers mostly have 5-6% deviation of the moisture content in one discharge of grain-mass [5], even though generally it should have homogenous moisture content distribution. By exploring the factors and solving the problems of the significant deviation of moisture content, energy saving and better grain-quality can be achieved, which means easier warehousing.

Optimal drying process realizes slow and gentle vaporization of water from the grain. The process takes only the necessary amount of water from the grain that is needed for the secure warehousing, while the technology prevents the locally overheating and over-drying of the grain mass. This process protects the quality of the grain while the energy consumption is kept on minimum level. Neither the modern grain-dryers give sufficient information about the drying-process for the operators. But most of the dryers can be fine-tuned using the precision drying methodology (some of them need small interventions, for others structural modifications are necessary after the problem identification). The precision drying is based on modern information technology (IT) devices, new data processing methods and it supplies much more information on the drying process than any other device before. It gives tight control of the drying process; hence, preserving of the grain

quality is important from the point of view the plant improvement, plant production and animal production also.
Besides preventing grain quality the moisture distraction practically should be gentle but maximum efficiency. Experience has shown that the precision drying principle based developments increased the performance and efficiency in most of the cases.

Scientific research has shown that if the mass temperature is over 50°C then unfavourable processes get started, and these causes the deterioration of the inner values of the grain (denatures proteins, oxidizes vegetable fats, inactivates enzymes and vitamins). The higher the mass-temperature, the risk of degradation of the grain quality will be higher too. It is very important to take into consideration this limitation during the development of the drying-process. Every outlet temperature and mass-temperature that is higher than 50°C causes loss during the operation of the grain dryer.
To realize precision drying more condition should be kept near to its optimum:

- homogenous heat-load over the surface of the tower,
- homogenous grain-mass speed everywhere in the dryer shaft,
- constant air-pressure over the surface of the tower [3].

More than 1500 grain-dryers works in Hungary during the harvesting period of the year. The investigation highlighted the fact that, most of the currently operating grain-dryers (even the newest ones) not satisfying the minimum requirements of precision drying. Most of them are not able to work on an optimal level, and achieve precision drying without some structural modifications.

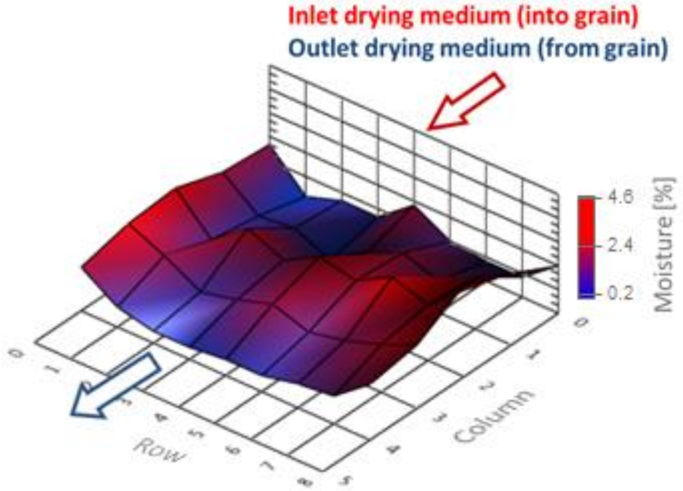


*Figure 1 Moisture content decrease (%) horizontally in the dryer, when the grain-mass steps out from the drying zone*

The moisture divergence in the discharged grain-mass is not caused by the big moisture content difference in the harvested grain, but the interference of physical effects in the tower (*Figure 1*). The cause of the previously mentioned significant difference (5-6%) in one discharge is more complex. The drying medium (homogenous temperature hot air) from the burner is evenly distributed through the product, which is slowly warming up the unique seeds from 8-10°C to 48-55°C during the water-distraction process (*Figure 2*).
In the Constant drying-speed section (1. section) all the heat given to the product goes for the vaporization of the moisture, the drying-speed (dx/dt) and the product temperature ($t_m$) are constant.
When the moisture decreases in the grain (x), the capillaries shrinks, the evaporation zone contracts to the centre of the grain, the mass temperature is increasing while the drying speed is decreasing (2. section). In the 3. section the drying speed is still decreasing, the mass temperature still increasing and the average moisture content is under the “secure storage minimum” in theory.

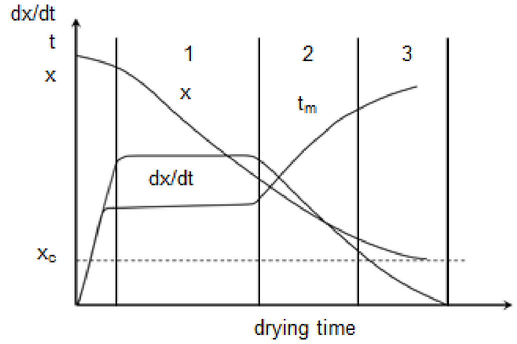


*Figure 2 Warm up of the grain-mass, „$t_m$" theoretical diagram*

A real measurement can be seen in *Figure 3*, which has been taken during maize drying. Left of the figure shows an optimal drying-process in the drying section of a tower. The grain enters on the top (cca. 20°C, designated by blue) as it flows down by gravity it slowly warming up to 50°C (designated by purple). During the gentle warming, the water evaporates from the grain. There are no red spots on the temperature distribution, which means there is no over-heating.

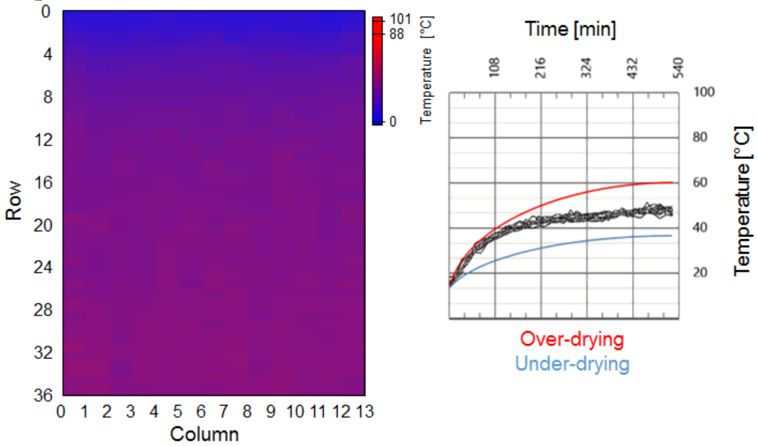


*Figure 3 Warm up of the grain-mass, „$t_m$" measured diagram*

The difference easily can be seen between the theoretical and the measured diagram, principally in the second section. The drying-speed (dx/dt) is not constant in the second section, but continuously increasing by the decrease of the moisture of the grain. There is no constant temperature section even over-drying is applied for some reason, in this case the mass temperature will be higher at the end of the drying section. The decrease of moisture content of the grain in *Figure 3* is similar to the "x" curve on *Figure 2*.

## 2. METHODS

We need a method to gain precise data from the outlet air-ducts of the grain-dryer, which can be used to identify the configuration of the dryer (temperature distribution, heat intensity, grain flow). Videokontroll is an industrial temperature measurement system that is able to measure air-temperature more than 500 measurement-points parallel. It measures the temperature of hot air all over the surface passing through the mass of grain at the time of exit (*Figure 4*). The system is able to point out the divergence of measurable parameters of grain driers form the optimal level. These parameters are: homogenous temperature and speed of the grain flow [2]. In case of divergence, the grain may get stuck creating jams, get fire, be over-heated (in this case the grain becomes fragmented and lose inner-values) or under-heated (in this case grains flow too fast and do not lose enough moisture, generating mold). The sensors can identify grain jams and measure the intensity of heat inside the dryer-shaft.

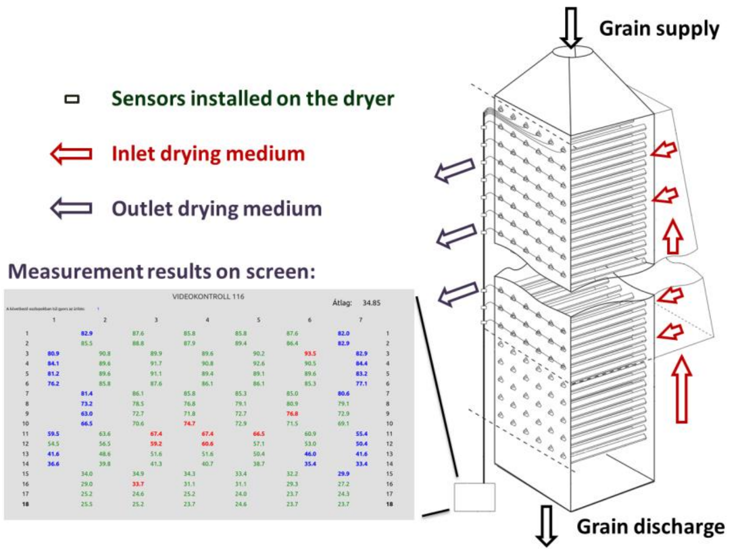


*Figure 4 Videokontroll measurement method*

The system measures temperature of hot air passing through the mass of grain at the time of exit from the outlet airducts, there is a strong correlation between the drying air temperature and the moisture content of the grain (the higher the temperature, the lower the moisture content of the grain). Using this information, we can get a so-called "thermal map" (*Figure 5*) about the vertical drying surface of the dryer shaft in front of the outlet airducts (the "cold-side" of the dryer).

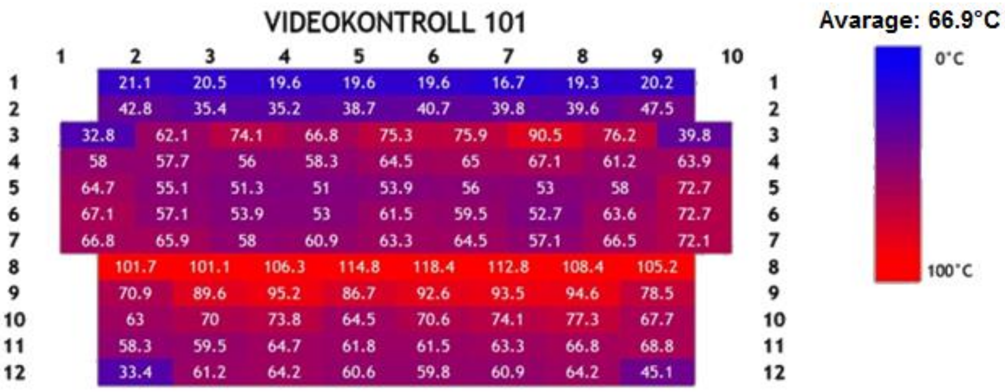


*Figure 5 Thermal map of a grain-dryer during maize drying (web-interface)*

A diagnosis can be set up based on the thermal map of the dryer, conclusions can be drawn about the configuration of the hot-side of the dryer (burner functionality, distribution of hot air in the air tunnel and on the surface, saturation of the air) and the dryer shaft (structural problems, air speed). If the problem is identified a solution can be elaborated upon it.

## 3. RESULTS

The main problems that were found at the grain dryers by the investigation in Hungary (most of them are modern dryers from the European Union) will be introduced in this part. Thermal maps sign the hot air by red, cold air by blue, 1$^{st}$ row and 1$^{st}$ column is always the upper left outlet air duct on the dryer column in the cold-side of the tower.

### *I. Asymmetry of heat load in the dryer section*

The asymmetric heat load in the dryer section can be caused by the asymmetry of the gas-burner and the inconvenient configuration of air tunnel over the burner.

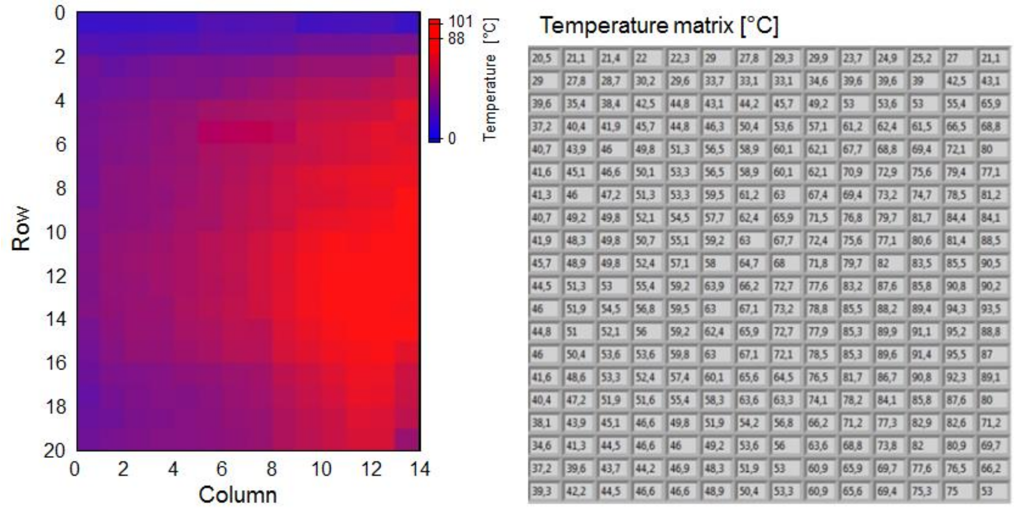


*Figure 6 Thermal map of a grain-dryer during maize drying (°C)*

On the right side of the drying shaft instead of 40°C, 90°C can be measured in whole season that can cause enormous energy waste, over-drying and problems during warehousing (5-6% difference of moisture content within one discharge cycle) (*Figure 6*). This deflection can be corrected by optimizing the configuration of the hot-side of the tower. During this process appropriate air flaps are installed over the gas burner to force the air to mix to gain homogenous temperature before it enters into the dryer shaft. Figure 3 shows the thermal map of the dryer shown in Figure 5 after the optimization process.

***II. Asymmetry of the discharge mechanism***

A physical phenomenon can be seen in *Figure 7*. The grain pouring into the dryer centre trickles clearly faster than the layers at the side walls, where the wall friction is retarding the flow [1]. Thus a grain column in the dryer shaft centre is clearly faster delivered than the remaining part in the shaft. The discharging mechanism should be corrected here to slow the grain flow in the shaft centre.

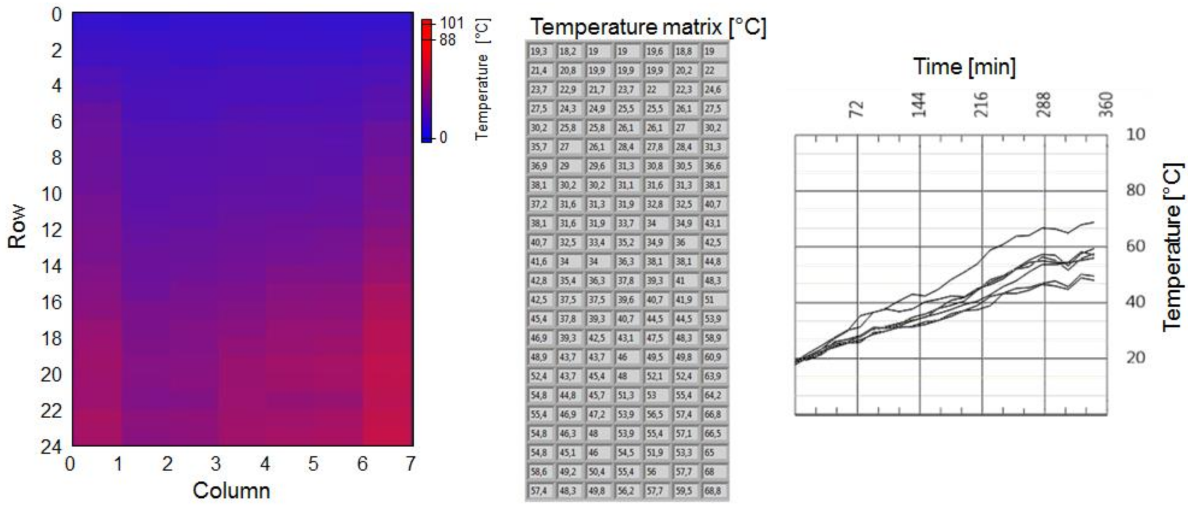


*Figure 7 Asymmetry of discharge is shown in 1st and the 7th column*

***III. Pressure parameters are unbalanced on the drying surface***

Unfortunately this is the main problem in most of the cases (*Figure 5*). The condition of the homogenous pressure is the homogenous structure of air ducts. If the air ducts are not distributed uniformly on the surface of the drying shaft, that will cause difference in air speeds and in drying efficiency also (*Figure 8*).

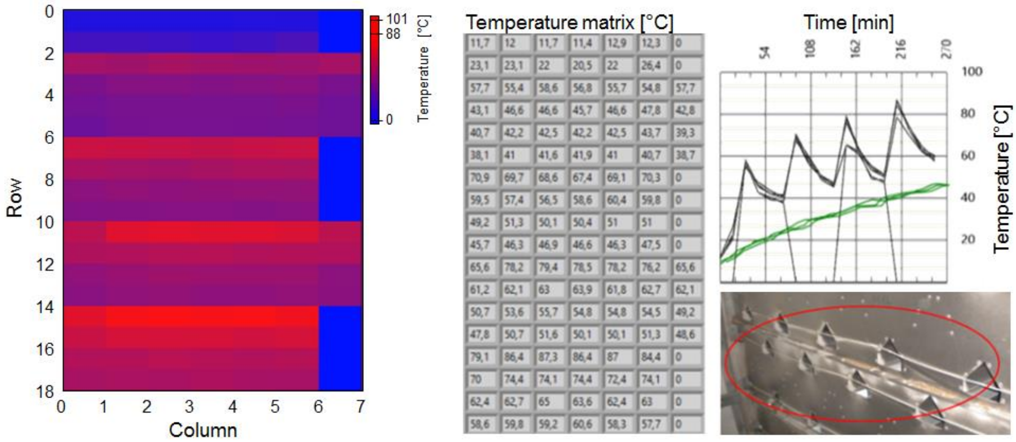


*Figure 8 Air ducts are not distributed uniformly on the surface (right), over-heating is present at every double line (left), the optimal process designated by green, the reality is by black (top-right)*

The over-heated horizontal lines exists because of the nonuniform distribution of airducts, at the irregular places the air-speed increase, even the maize is pulled out by the airflow from the dryer. The red lines means energy-loss, if the overheating can be ceased, then up to 20% energy saving can be realized. Correction of this problem is possible it requires disassemble the dryer and re-assemble the dryer shaft with an appropriate distribution of the airducts. The correction is a good investment, it retains in the first year.

## CONCLUSIONS

Precision drying makes the drying process transparent and more secure, that results better quality of the dried grain. The data set were collected on 12 different types of grain dryers, which covers the most generally used dryer types in Hungary and the European Union. The investigation determined that most of the dryers in Hungary need some modification to work on an optimal level. Through precision drying the drying process can be optimized, which can generate considerable cost reduction each year for the agricultural holdings. The transparent drying process ensures better quality of dried grain (proteins, vitamins not destructed), more secure drying process (reduced fire hazard) and warehousing (no microbes, no dust) and less energy consumption, less $CO_2$ emission.

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