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THERMAL INFORMATION IN GRAIN STORAGE BIN BASED ON COMPUTATIONAL MODELING AND SENSORS AUTOMATION

Paulo E. Cruvinel – cruvinel@cnpdia.embrapa.br
Embrapa Instrumentação Agropecuária
CP 741 –13560-970 – São Carlos, SP, Brasil

Abstract. *This paper presents a computational modeling for studying thermal behavior of grain storage bins, which is useful for increasing the safety margin of storage processes. The technique is based on advanced computer graphic interface model combined with a system for temperature sensors automation. Validation of the method was obtained by considering a B-spline interpolator for mapping the spatial and temporal variability of the temperature in a case study for these bins.*

Keywords: Computational modeling, agricultural bins, pos-harvest losses, spline functions, thermal mapping

1. INTRODUCTION

In the effort to increase productivity and improve quality at lower cost while at the same time minimizing environmental impact, computational modeling together with recently mechanized equipment are finding increasing applications in various agricultural sectors. This will be happening on a massive scale in the coming decades as this pursuit continues.

In Brazil, for instance, the specific case of grain, at present about 20% of national production is lost during storage and transportation. By correcting these systems, this figure can be reduced. Thus, improvements in grain treatment and storage in, for example, the case of bins and agricultural dryers, through access to and use of reliable data on thermal variations would undoubtedly contribute, by optimizing decision-making during the aeration process, to substantially minimizing storage problems (Balsani, 1999).

Understanding the drying process in dryers or bins of agricultural products requires monitoring of, among other variables, product temperature, in addition to its quantification in order to validate models simulating grain drying. To this end, thermal modeling of grain storage bins is necessary so as to make it possible, among other things, to obtain temperature measuring points to allow effective monitoring during the storage period. Also required are profile evaluations and thermal gradients, considering its influence in grains humidity during storage. Humidity levels ranging between 12% and 14% are considered safe for cereal grain storage for up to one year following drying.

Grain storage planning and management requires predictive capacity and understanding under different climatic conditions. This can be arrived at through experimental procedure analyses, although a less expensive and more far-reaching alternative is prediction by means of computational models. Such models can also be used to study temperature behavior inside bins as a function of their size, construction material used in their walls, and geographic location. Inversely, desired thermal profiles can, through modeling, be used to determine the physical characteristics of a bin (Alagusundaram et al 1990, Yaciuk et al 1975, Muir et al 1980, Longstaff & Banks 1987, Wide & Sohlberg 2002).

This paper presents a computational modeling for grain agricultural bins based on real-time temperature monitoring and prediction.

2. DEMANDS UPON AGRICULTURE

Many of the demands placed upon agricultural processes will be met by extension of existing computational modeling and technology. However, an apparently monitoring system can be obtained if digital signal processing is incorporated within the sensors package together a decision making environment. The advantage of this is the possibility to converse with distributed and central processing facilities without the need for complex conversion systems.

Besides, during the past decade different methods have been used for temperature monitoring in many applications, including agriculture. New monitoring technologies in this area include the development of silicon-based sensors, image-based sensors, fiber-optic sensors, new materials such as polymer, dedicated architectures and specialized software's. Also, the development of monitoring systems for decision-making in agriculture processes is a quite new area. It is related with the development of systems for making decisions concerning the information on time and spatial variability.

Environmentally friendly innovations and procedures are crucial and will likely become ever more so. Grain-temperature monitoring during bin storage is fundamental in the decision to aerate when heated areas are detected in a grain mass through the models.

3. METHOD AND RESULTS

To succeed in monitoring the temperature in grain-storage bins, a system was used whose architecture is based on intelligent modules for data acquisition, together with another module having a host function with respect to the system as a whole. In the tests, three acquisition modules were used, each of which had 8 sensors plus a host module which was connected to a computer by using standard RS-485 for serial communication, allowing information exchange between more than two interconnected devices by means of a pair of metallic wires.

All the system modules (the acquisition ones plus the host module) originate in a circuit whose processor is an 80535 microcontroller. The sensors utilized were types PT100 in a Whetstone bridge configuration. A conditioning circuit of the signal originating in the temperature sensor through the utilization of operational amplifier LM725 configured as a differential amplifier which intensified the difference in potential in the branches of the Whetstone bridge in order to condition the voltage variation in proportion to the temperature variation reported by the sensor (between 0V and 5V), which is then applied at the entrance of the analog to digital converter of the microcontroller 80535.

As an integral part of the decision-making system, an application was developed for IBM-PC computers with a Microsoft Windows platform. This was done using a Borland C++ Builder. The principal application functions are to receive data stored in the host module and store them in a database so that this information can be retrieved, making possible data analysis and thermal map generation. The data base organizes the information into so-called experiments, i.e., groups of data from one or more samples from the same bin, thus making it possible to accumulate a record describing thermal behavior during a given period.

The data collected contains precise information on temperatures at the places where the sensors were placed. An option exists to expand this information by interpolating the data within a given area delimited by the sensors. For interpolation, the cubic spline method was used. This is a polynomial function with continuous parts, each of which is a 3 degree polynomial with continuous first and second derivations so that the interpolated signal has neither peaks nor abrupt curvature changes in known points, making this function suitable for representing thermal variations.

Figure 1 shows temperatures on a gray-level scale and interpolating some known values, a thermal map or image can be obtained which makes possible improved spatial temperature variability analysis of pre-established planes.

The use of these maps or images makes it much easier to understand thermal behavior in bins; many image sequences varying with time can be generated, obtaining in this way animations and a structure making possible temporal series analyses of thermal variations.
The user can establish temperature thresholds, which must be renderized, an option of great usefulness since certain temperature ranges are propitious to fungus development in bin-stored grain. This resource simplifies the process of identifying problematic regions, their extension, and prevailing temperatures and their duration.

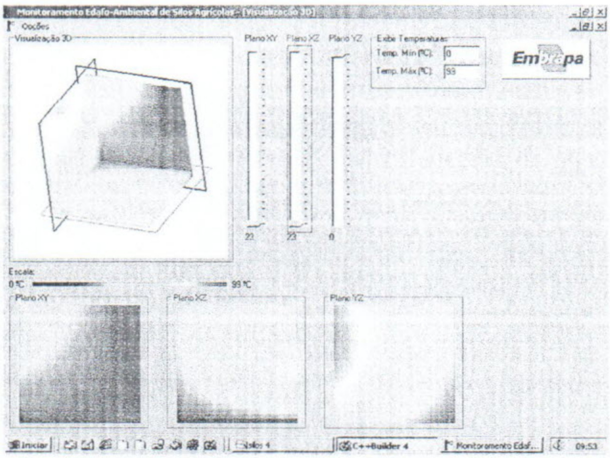

Figure 1 - Gray-level representation of temperature variation in a agricultural bin.

4. CONCLUSIONS

A thermal monitoring and decision making method for reducing grain loss in bins was presented. The solution proposed offers an innovational, reliable, and easy to use methodology, which makes possible efficient management of information relative to spatial and temporal variability of thermal gradients occurring in agricultural bins. And, of course, efficiently managed information, which is fundamental in guaranteeing stored grain quality. The choice of OpenGL and C++ programming language conferred portability, flexibility in integrating other systems for decision-making in agriculture, and simple implementation.

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