Computers and Electronics in Agriculture 116 (2015) 45–54

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Thermistor based system for grain aeration monitoring and control

Antonio José Steidle Neto, Daniela de Carvalho Lopes *

Federal University of São João del-Rei, MG 424, km 47, Sete Lagoas, Minas Gerais CEP 35701-970, Brazil

ARTICLE INFO

Article history:
Received 24 November 2014
Received in revised form 8 June 2015
Accepted 8 June 2015
Available online 25 June 2015

Keywords:
Grain storage
Instrumentation
Sensors
Thermometry

ABSTRACT

Aeration is a popular tool, used to modify the grain bulk microclimate and to control the product quality. The aeration controllers are designed to provide automatic starting and stopping of aeration fans based on a selected strategy. However, most of the already proposed automatic controllers are unviable for small and medium farmers due to the high capital costs associated with them. In this work a low cost aeration controller is proposed, which should be easily adopted for small and medium farmers located in different regions of the world. The proposed controller is called AERSY and is based on the AERO control strategy joined to a low cost data acquisition system with thermistors. AERSY was tested, presenting reliable operation. The aeration control strategy was also efficient in maintaining safe storage conditions during the studied period, but the simulation procedures can be improved regarding the grain moisture content estimations. When comparing the capital costs for installation, AERSY was 44% cheaper than an aeration control system with the same features, but based on thermocouples. The system was found to be suitable for use mainly in small and medium silos (up to 8000 m^3) but it can be adapted for use in larger storage facilities.

1. Introduction

The progressive worldwide population increase has brought a growth in food requirements and, consequently, in cultivation expansion. There is a global concern about food shortage and the need to increase agricultural production. However, the better grain yields have been prejudiced by limited storage capacity, which has increased the risk of grain spoilage due to insect infestation and mold growth. Further, prices tend to fluctuate, mainly during the growing seasons. This scenario is contributing to a global on-farm storage increase.

A significant economic benefit of safe grain storage by small and medium sized farmers is that they will not be put under pressure to immediately sell their grain. This allows farmers the option to delay selling while negotiating a better price, also helping the farmers to get a fair price for their product and limiting the role of intermediaries. Further, safe storage can also help small and medium sized farmers to access credit since they can pool their grain, store it and then sell as a group enabling them to market good quality and large volumes (Taruvinga et al., 2014).

Grain aeration is a process of great relevance to post-harvest engineering and has been widely used in stored-grain management in North America (Edde, 2012), Australia (Nawi et al., 2010), Brazil (Lopes et al., 2008a) and other countries (Jayas, 2012; Navarro, 2012). This technology is used to modify the grain bulk microclimate, reducing or eliminating harmful or damaging organisms by maintaining grain temperatures and humidities at safe levels.

Typical aeration systems include the storage structure with perforated in-floor or on-floor ducts, connected to a fan which forces air through the grain. These systems also require one or more roof vents for exhaust or air intake. The aeration controllers are designed to provide automatic starting and stopping of aeration fans based on a selected strategy, usually based on temperatures and humidities deemed suitable. These controllers should be from simple mechanical equipment to complex electro-mechanical ones, including microprocessor and computer-based aeration control systems (Navarro et al., 2012).

Automatic controllers are ideal for grain aeration management since they allow more complex strategies. Also, with this kind of controller it is possible to integrate the management of thermometry systems and electronic devices capable of operating the fans. Numerous automatic controllers have been developed throughout the world for this purpose (Agridry, 2014; Ferraza et al., 2010; Fockink, 2014; Hung et al., 2009; Lopes et al., 2008a).

However, as the capital cost of an automatic aeration control system is often the most critical issue to potential users, most of the proposed systems are unviable for small and medium sized farms. Also, some automatic aeration controllers have often been

* Corresponding author. Tel.: +55 31 3697 2039; fax: +55 31 3697 2022.
E-mail address: danielalopes@ufsj.edu.br (D.C. Lopes).

http://dx.doi.org/10.1016/j.compag.2015.06.004
0168-1699/

abandoned by stored grain managers soon after installation due to the inadequacy of the control strategy to accommodate local weather conditions, impeding the system to achieve the desired control objectives (Navarro et al., 2012).

Thermocouples are the most widely used temperature sensors in the grain industry. But, thermometry systems can also be based on thermistors, resistance temperature detectors (RTD), addressable devices (integrated circuits), radiation devices, and other electronic temperature sensors. In general, thermocouples are used in industrial applications because they work reliably at wide temperature ranges, are robust, self-powered and less expensive than addressable devices and radiation sensors.

However, the temperatures measured during grain storage are less than 100 °C, which allows developing and using inexpensive and simple sensors. When thermistors are compared with thermocouples their long-term stability, resolution, accuracy and precision are somewhat better. Also, thermistors are more sensitive and cost less, presenting high output signal and low response time. The thermistor is the most accurate (±0.01 °C) of the electronic thermometers, and has the highest resolution (DeFelice, 1998). These sensors are available in many different base resistances and curves, requiring a suitable specification to each application (Enercorp, 2014).

In this context, the current work was carried out to propose a low cost aeration controller, which should be easily adopted for small and medium farmers located in different regions of the world. The proposed controller is based on the AERO control strategy (Lopes et al., 2008b) and in a low cost thermistor data acquisition system (Steidle Neto and Zolnier, 2006).

2. Methodology

2.1. The low cost aeration controller

The AERSY (AERation control SYstem) is composed of temperature measurement devices (sensors and circuits), an aspirated psychrometer, and a relay circuit for fan operation, phone cables, a software package, and a personal computer (Fig. 1).

2.1.1. Temperature measurement devices

The circuits for measuring the grain temperatures are the main factors responsible for the low cost of the AERSY controller. The temperature measurement device was proposed by Steidle Neto and Zolnier (2006). It is composed of a thermistor with Negative Temperature Coefficient (NTC) and simple electronic components (Fig. 2). In this work the circuits were mounted on phenolic boards of 100 cm^2.

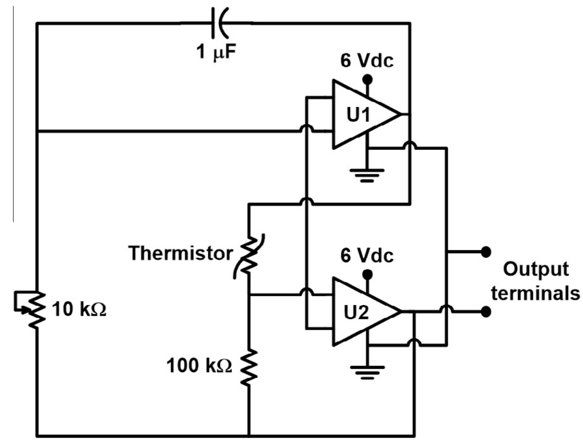

Fig. 2. Electronic diagram of the proposed temperature measurement device.

The features of the NTC thermistors were base resistances of 10 KΩ (±3%) at 25 °C, operating ranges of −55 to 125 °C, beta constant of 3970 (±1%) and body diameter of 3 mm.

The thermistors were connected to parallel phone cables of 2 × 0.28 mm^2. These were connected to the electronic circuits, allowing that only the temperature sensitive elements were in contact with the grain bulk.

In this study, elements U1 and U2 were operational amplifiers contained in the integrated circuit LM324. This electronic component presents four independent amplifiers, which allows mounting two temperature measuring devices by using only one LM324. This chip should be fed by voltages from ±1.5 to ±15.0 Vdc. But, in the proposed system it is recommended that this value does not exceed 6 Vdc due to the parallel connection interface between the electronic circuits and the personal computer. Alternatively, two integrated circuits LM741 or CA3140, which contain only one operational amplifier, should be used to replace the LM324.

The outputs of temperature circuits were connected to DB25 connectors, which have an 8-bit data bus and 25 pins. The DB25 connectors were plugged to 1p-USB converters (Comm5, 2014), which are USB cables capable of virtually installing bidirectional parallel outputs (LPT ports). This interface supports parallel communication, which is a simple and inexpensive tool for control projects. Of the 25 available pins, five should be used for data

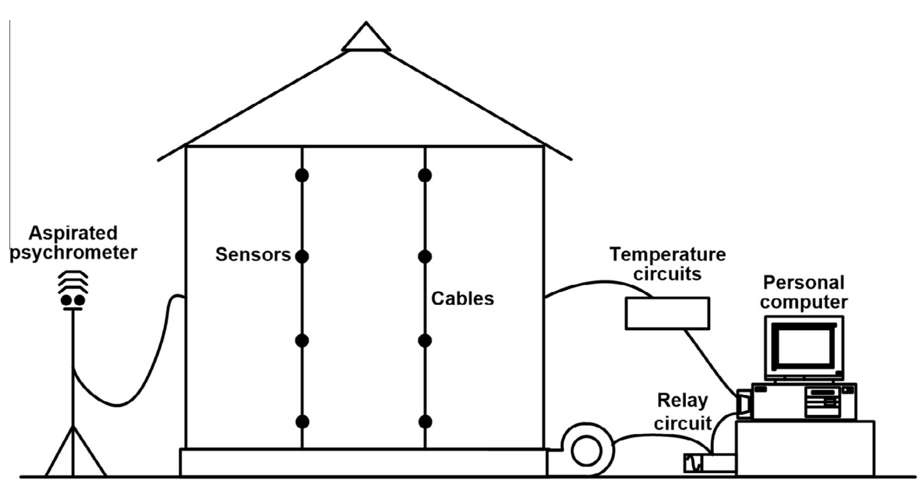

Fig. 1. General schematic diagram of AERSY.