Aeration Manager

THE AERATION MANAGER
WITH
ADAPTIVE DISCOUNTING CONTROL
OVERVIEW AND FEATURES

AERATION CONTROL
AUSTRALIA

CSIRO

Contents

Preface

Aeration is a common and flexible grain storage tool which is experiencing increased demand around the world at present. Aeration systems pump air through a grain bulk using an arrangement of ducts, exhaust vents and fans. The aeration air is selected from the local ambient air with an automatic controller for reliable results. It can be used for drying, cooling or ensuring safe long-term storage and applied to all grain types.

A seven year collaboration in Australia between Aeration Control Australia and the CSIRO has seen the implementation of years of scientific research by The Stored Grain Research Laboratory (SGRL) and the Grains Research and Development Corporation (GRDC) come together into the creation of the Aeration Manager. This involves using a novel aeration control method designed to improve the drying and cooling of agricultural commodities.

This new method is called "adaptive discounting" and implements all modes of aeration; drying, cooling and maintenance. The method offers the capacity to target out-turned grain moisture and/or temperature conditions, high efficiency, a "user friendly" interface, and a simple but sound technical basis. .

A key innovation of the Adaptive Discounting control method is the novel link between the air condition selection process and induced changes in the grain temperature and moisture conditions. This is achieved by predicting "on the run" the time period required for fronts to propagate through the grain and adapting set points accordingly. As a result, the method propagates fronts through the grain bulk being aerated until the target grain moisture or temperature is obtained.

This document provides an overall description of the Aeration Manager and its features.

1. The software

The Adaptive Discounting Control method (ADC) is software developed by the CSIRO.

A license agreement between the CSIRO and Aeration Control Australia has seen this software implemented in the Aeration Manager.

The controller accepts inputs specifying the following information.

- Grain store parameters
- Aeration equipment parameters
- Current grain condition
- Target grain condition
- Time and date
- Ambient weather
- Feedback from aeration equipment

2. Industry trends

The vast majority of grain produced in Australia will be stored for some period of time, either on the farm, by bulk handlers or traders. The Australian grain industry is changing dramatically following deregulation of the state bulk handling and marketing authorities. Growers are adopting on-farm storage at an unprecedented rate and traders are pursuing an increased presence in the market. These changes are challenging the existing post-harvest supply chain infrastructure at all levels in the pursuit of fast throughputs, just in time supply, lower costs, diversification of products and services, segregation, capacity to out-turn higher value grain parcels, and ultimately the question of "who's in control".

Australian commodity statistics demonstrated that Australia's grain production continues to steadily increase with a 10 million tonne increase over the last decade. With the ever-present pursuit of increased plant yields, adoption of intensive farming practices, the overall trend of increased grain production is expected to continue even if hectares planted does not. Local seasonal influences will always cause substantial yearly fluctuations, especially on a regional basis.

Cropping practices continue to evolve. Farms are increasing in size to improve the economic productivity of large capital investments with advanced grain harvest, conditioning and storage complexes increasing. Harvest weather risks are being minimised with drying systems, the raising of receival moisture limits recently on most cereal grades, and greater heading capacity. Many growers have acquired aerated stores allowing harvesting at higher moistures to improve harvest flexibility and reduce risks.

These changes and trends within the storage sector have led to an increasing use of aerated storage. There are a wide range of individual benefits, but the main benefits currently pursued are capacity for holding or drying "wet" grain to enable harvesting of wet grain; control and manipulation of grain quality during storage; suppression of stored product insects without chemicals; and ensuring safe long-term storage. Aeration can be applied to all grain types and in most cases is very cost effective in both capital and operating terms.

Aeration is the pumping of air through grain in a store to gradually change the moisture or temperature of the grain. Different grain moistures or temperatures are required depending on the benefit pursued. The final grain moisture or temperature conditions achieved depend on the air selected and grain conditions. Air conditions vary across Australia according to climate, location, time of day and time of the year. An aeration controller is used to select air of the required conditions to achieve the final grain moisture or temperature wanted.

3. Aeration controllers

The traditional use of aeration in Australia was non-specific grain cooling and most available control options relate to this application. The dominant cooling controller on the Australian market is the time proportioning controller, an early CSIRO development. This controller was introduced in the late 1960s in Australia and provides a combined grain cooling cum moisture migration prevention action for implementing with typical aeration-cooling system capacities of 1-3 $Ls^{-1}t^{-1}$. ***It does not address all the requirements of modern industry trends, nor was it designed to.***

There are basically three main modes of aeration control: drying, cooling and maintenance. Each mode requires the selection of alternative air conditions. Drying selects dry thus warm air, cooling selects cool thus predominantly moist air, and maintenance seeks out the small amounts of dry and cool air available. ***A multipurpose controller offering drying, cooling and maintenance control actions is now available in the form of the Aeration Manager.***

Most aeration control methods are purely air selection based methods and do not account for the aeration system that is being controlled. The same air selection process is implemented regardless of required grain conditions, starting grain conditions, aeration system capacity or progress of the aeration process. Creating a link between the controller, the aeration equipment and the aerated grain provides an aeration system that responds correctly to most factors; the particular benefit wanted; the inloaded grain conditions; the range of store sizes and types; different fan sizes, and the range of weather conditions that can occur. Also, without this link, energy efficiency is lost and aeration continues when unnecessary.

A couple of control methods involve placing a sensor or sensors in the grain to create the link between the progress of the aeration process and the control method. If sensors are implemented correctly this can provide a suitable link, but there are concerns about the high cost of sensors, durability of sensors, and having to address issues of correct placement of sensors in the grain.

Most control methods often require significant operator skill and daily attention to be effective. Users can be required to determine specific criteria such as relative humidity or temperature settings, rain-out limits, appropriate operating hours, or predetermined operation “rates”. These values can be required at particular times throughout the aeration process. Typical aeration users are seasonal staff, growers, etc, who are unlikely to have training in aeration details, nor reliably interact with the controller at key times to enable effective operation due to other demands on time. This is often coupled with confusion over what performance should be expected of aeration controllers. ***The Aeration Manager will not require such skills or interaction from users.***

Several industry trends require that a relatively uniform final grain condition be created during aeration. Insect suppression will be effective if all the grain has a temperature in the range of 15℃ ± 3℃ without any parts of the bulk being above 22℃. Cereals are reliably traded and saleable weight is not lost if dried to a moisture less than 12%, without any parts being above 12%, but not over-dried to 10%. A controller that can select air such that total grain bulk is at the required moisture and/or temperature condition will meet such needs.

4. The Adaptive Discounting Control method.

To meet current industry trends and address the identified omissions, a new control method, Adaptive Discounting Control (ADC), was developed at CSIRO Entomology.

The term adaptive discounting portrays the major characteristics of the ADC method. Adaptive refers to set points being adapted or changed during the control process by the control action. (Adaptive is a term common in control engineering.) Discounting refers to the discounting of aeration control set points which is an innovation of this control method. During some weather conditions, an aeration process can dry or cool grain more than required. This grain has experienced "extra" drying or cooling. The controller determines when this occurs and adjusts its set points to use up the extra drying or cooling, enabling faster aeration and less over-drying. In this way, air that would normally have been rejected will be put to good use.

Overall, the ADC method will implement all modes of aeration (see Appendix 7.1) and target specific grain moisture and temperature conditions. The method focuses on propagating fronts through the grain bulk by using the capacity of the aeration system, the specific aeration rate. A feature of the method is a user friendly interface that incorporates inputs that are known and understood by typical users.

Following liaison with industry, a "set and forget" feature is utilised that only requires interaction when the grain is loaded into store, and sensors within the grain mass were avoided.

A key innovation of the ADC method is the novel link between the air condition selection process and induced changes in the grain temperature and moisture conditions. This is achieved by predicting "on the run" the grain conditions being achieved and the time period required for fronts to propagate through the grain. Set points are adjusted on the run accordingly. As a result, the method propagates fronts through the grain until the target grain moisture or temperature is obtained.

5. Features of the Aeration Manager

The main features of the Aeration Manager are summarised here. Most of these features were specifically designed to address the industry trends and controller limitations described in sections 2 and 3.

5.1. A multipurpose controller

The Aeration Manager was designed as a multipurpose controller that can be used for each or all aeration modes; drying, cooling and/or maintenance. The ADC method used is based on well-known aeration fundamentals and will operate effectively in all locations and at any time of the year. The method automatically switches from dry to cool to maintenance as each aeration action is completed, but will omit actions that are not required.

5.2. A “user friendly” interface

One of the most important design requirements of the Aeration Manager was to ensure that the user interface was practical and realistic based on a series of design features. These are:

- Inputs required from typical users were easily understood and available.
- A “set and forget” interface
- In-store sensors are not required.
- Dynamic User interface

5.3. Easily understood User inputs.

The Aeration Manager interface requires a set of readily obtainable inputs from Users. In general terms, the inputs for typical users are as follows.

- grain type
- inloaded grain moisture and temperature
- required grain moisture and temperature
- mass of grain to be aerated

5.4. In-store sensors are not required.

The ADC method does not require the use of in-store grain sensors such as temperature cables or inlet/outlet humitters and the like for effective operation. This has been addressed by the control method being able to predict when the aeration process had changed the grain conditions sufficiently based on knowledge of the capacity of the aeration system being controlled.

5.5. Dynamic User inputs.

The user inputs can be changed at any stage during the operation of the control method and the control method will continue controlling appropriately. A user does not have to restart the aeration process if input errors or changes to desired outcomes are wanted during an aeration process.

5.6. Linking the controller to the aeration system

A key innovation of ADC method is the indirect link between the air condition selection process and induced temperature and/or moisture changes in the grain. This is achieved by predicting “on the run” the time period required for fronts to propagate through the grain and the extent that drying or cooling being achieved. Set points are adapted during the aeration process accordingly. As a result, the method can track aeration progress amid a wide variety of weather and grain conditions. This enables the Aeration Manager to propagate fronts through the grain bulk until the target grain moisture or temperature is obtained and can provide a wide range of feedback information.

5.7. Target grain conditions

The Aeration Manager was designed to aerate grain until a target grain moisture and/or temperature is achieved. The controller also provides an advanced option for selecting a minimum grain condition; moisture content for drying mode and temperature for cooling mode. Minimum moisture contents can be useful for preventing cracks in breakage sensitive grains such as corn, rice, peas and beans. Minimum temperatures can be useful for preventing overcooling with grain conditioning operations that include fumigation, noting that fumigation is slow with grain less than 20℃.

5.8. A "safety first" control strategy

The Aeration Manager was designed to ensure grain quality was not put at risk during aeration under any weather conditions or initial grain conditions. This is achieved by several aspects of the control method design that operate simultaneously.

Firstly, the drying or cooling capacity of the natural air is selected in direct proportion to the drying or cooling need of the grain. This causes the proportion of the day that the controller operates fans to increase when need is greater. For example, very wet grain will be aerated almost continuously (apart from fog and rain) while just wet grain will be aerated with a smaller proportion of each day. So self heating and mould development in wet grain is addressed in direct proportion to the risk.

Secondly, the controller propagates complete fronts through the grain even if the target moisture or temperature has not been achieved with the current front. This ensures that all the grain in the store is dried or cooled at the fastest rate possible with available air, before restricting aeration. For example, it is better to rapidly dry all the grain 4 percentage points from 20% to 16% and substantially restrict selfheating and mould development, compared to slowly drying half the grain 8 percentage points from 20% to 12% and leave half the grain undried at 20% for a considerably longer period, risking heating and mould development.

Thirdly, the controller implements cooling with an accurate and safe grain rewetting prevention action (as part of discounting action). Cool air is usually wet air. A common assumption with aeration cooling is that the amount of rewetting of the grain near the inlets during aeration will be negligible. This is based on an assumption that is reasonable for aerating dry grain at many inland locations away from winter. The ADC action allows cooling with wet air while the amount of rewetting does not cause the moisture content of the grain near the inlets to exceed the target moisture. So all locations, grain conditions and times of the year are catered for without using relative humidity limits that can excessively restrict aeration, slowing cooling dramatically in some scenarios.

5.9. Good energy efficiency

The ADC method is energy efficient. Aeration will only occur if an appropriate front is being progressed through the grain. For drying, this is achieved by aerating with air that is drier than the grain, or if the drying process is achieving more drying than needed, aerating so that the average of all the inlet air is achieving the target moisture. ***Energy is consumed to operate the fan only when grain is being dried to achieve the target moisture content. A similar process occurs for cooling.***

5.10. Maximum drying or cooling rate

The ADC method progresses fronts as rapidly as the available air will allow while not incurring risks as explained in section 5.8. The discounting component of the ADC method releases the set points to allow the fan to operate as close to continuously when ever the target moisture or temperature is being achieved with the current front. Furthermore, the discounting action is used to prevent excessive restrictions of aeration cooling in the attempt to prevent rewetting as explained in section 5.8. This ensures that all the grain in the store is dried or cooled at the fastest rate possible with available air.

6. Appendix

6.1. The basic modes of aeration; dry, cool and maintenance.

There are three basic modes of aeration; drying, cooling and maintenance.

Aeration drying systems target final grain moisture and have the capacity to dry the grain at any time of the year, particularly during the autumn and early winter harvest period. Greater harvest flexibility and control over grain quality factors that depend on the timing of harvest can be achieved. This category is particularly relevant to summer crops and coastal grain harvesting locations.

Aeration-cooling systems target a final grain temperature and have the capacity to cool the grain at any time of the year, particularly during summer. Specific grain quality parameters can be maintained and insect numbers can be suppressed. This category is most relevant to winter cropping.

Aeration-maintenance systems prevent storage spoilage caused by seasonal weather change, low level insect heating or slow biological respiration. Such systems are the most efficient for reliably controlling storage losses in dry grain stored for the longer-term without excess investment in capacity. Maintenance systems are also ideal for integrating with fumigation systems. This category is most applicable to large stores, i.e. hundreds to thousands of tonnes.