

## Optical Sorting for the Cereal Grain Industry

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**Abstract:** Optical sorting adds value to cereal crops by removing blemished grains and foreign material. Sortex have been designing and manufacturing optical sorting machines for bulk inspection and grading of food for over 50 years. In this presentation, we outline the fundamental principles underlying the design and operation of an optical sorting machine in terms of the four main functions of feed mechanism, inspection system, image processor and ejection system.

The Z-Series is the very latest machine made by Sortex. The innovative design of the Z-Series has resulted in a step change in the performance achievable by optical sorting. This technological innovation has created new applications for optical sorting within the cereal grain industry. Results are presented of the performance of the Z-Series for sorting cereal grains. The results include the removal of dark, discoloured, un-hulled and foreign material from Buckwheat at throughputs of up to 14,000 kg/hour.

## 谷类谷物工业的光学分选在荞麦上的应用

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**摘 要:** 光学分选对于消除缺陷谷物和杂质增加谷物收获的价值。Sortex 色选机一直在设计和制造光学分选机用于散装检测探测和食品评级方面有 50 多年的历史了。在本介绍中我们概括了设计和操作优选光学分选机的基本原理, 按照三种主要功能, 即喂养机构, 探测方法和排斥系统来说明。Sortex 的最新型的机器是 Z- 序列机器, 这一 Z- 序列创新设计产生光学分选能达到的大步改进, 这种技术革新创造了加工谷物工业中光学分选的新应用。结果呈现在 Z- 序列对于分选谷粒的功绩。结果包括去处暗色, 变色, 未去壳的和荞麦原料中的杂质。产量可达 14000kg/h。

### Introduction

Traditionally, the cleaning of defects from wheat is carried out by mechanical machinery. In this paper, we introduce optical sorting as a new alternative to the mechanical cleaning of wheat. Unlike wheat milling, optical sorting has been an essential part of rice milling for many decades<sup>[1,2]</sup>.

Recent improvements in the design of optical sorting machines have led to a step change in performance. An example of a modern optical sorting machine is the Z-Series -- the latest machine made by Sortex, see figure 1. The Z-Series was originally designed for the cleaning of rice<sup>[3]</sup>, but has now been successfully adapted and used for the cleaning of wheat<sup>[4]</sup>.

The contribution of this paper to the academic community is to highlight this transfer of technology from rice into

wheat milling and to explain the improvements in optical sorting machines that have made this transfer possible.

The layout of the rest of this paper is as follows, first we describe the basic operation of an optical sorting machine, this sets the framework for describing recent advances in the design of an optical sorting machine. Results are presented from trials of sorting buckwheat. The paper concludes by returning to the theme of technology transfer to predict a future trend in wheat milling.

### Principle of operation

An optical sorting machine consists of four main parts: a feed mechanism, an inspection system, an image processor and an ejection system, see figure 2.

The feed system presents the grains to the detection and the ejection systems in a controlled manner. The feed



Note the modular construction based upon 4 separate chutes arranged side by side within the frame.

Fig. 1 A photograph of the Z-Series, an optical sorting machine designed and manufactured by Sortex

system consists of an input hopper, an in-feed vibrator and a chute. The grains are inspected after they have left the end of the chute.

The inspection system comprises of cameras, foreground and background lighting. The inspection system measures the reflectivity of each grain as it passes in front of each camera. The reflectivity responses of the grains are processed by the image processor (not shown in figure 2). The image processor identifies defects and the location of these defects within the product stream.

The ejection system comprises an array of air ejectors. The good product is allowed to pass straight through the machine, whereas the defects are rejected by the ejection system. The ejection system uses the location information from the image processor to accurately aim short bursts of compressed air at the defects.

#### Feed mechanism

The throughput of an optical sorting machine is governed by the width of the chutes, increasing the width of the chutes increases the throughput. Early optical sorting machines had narrow chutes, whereas modern machines have much wider chutes (300mm on the Z-Series). The chute is inclined at a steep 60° angle so as to accelerate the product. This acceleration aids in the separation of the grains into a uniform mono-layer which improves both identification and rejection of defects. There are two different types of chute: flat chutes for the first (primary) sort and channelled chutes for a resort of the rejected product. The purpose of the resort is to reclaim the small percentage of good product falsely

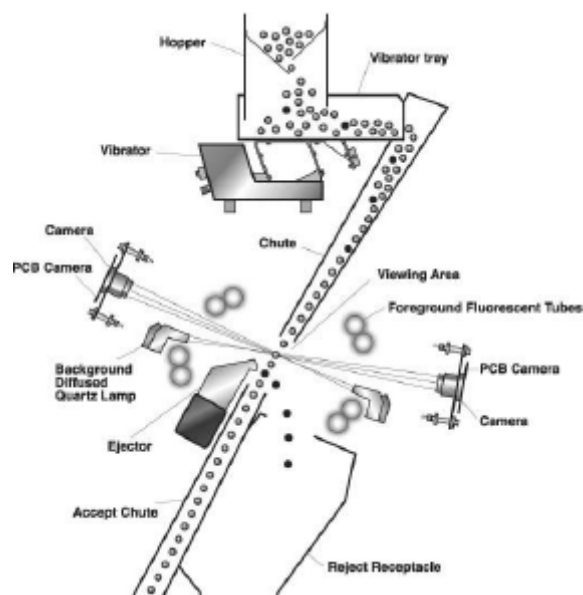


Fig. 2 A cross-sectional view of an optical sorting machine

rejected by the primary sort.

#### Inspection

Early optical sorting machines used low resolution photodiode technology to image the product. Modern optical sorting machines use high resolution charged coupled devices (CCDs). There are two reasons for using high resolution CCDs rather than low resolution photodiode technology. Firstly, increased optical resolution means smaller defects can be identified. Secondly, the sophisticated image processing techniques (described in the next section) for shadow-removal and object location require high resolution image data. The CCD camera used in the Z-Series has 2048 pixels viewing the 300mm chute width.

Placing optical filters in front of the camera can enhance the difference in reflectivity between the good product and defects.

Organic and inorganic materials have different reflectivity responses to near-infrared light. The use of modern near-infrared cameras to complement visible cameras has increased the performance in detecting foreign bodies and contaminants<sup>[5]</sup>.

#### Image processing

The image processor identifies defects by applying a four-stage process. First, a shadow filter is applied to ignore dark regions in the image caused by shading at the edges of

grains. Next, each image pixel is compared to a brightness threshold to locate potential defect pixels. Then, regions of defect pixels are spatially filtered to ignore defects less than a specified size. Finally, the image processor analyses each grain, either individually or as part of a small group of grains, if a grain is identified as a defect then the image processor calculates the precise location of that grain and outputs this location information to the ejection system. This precise aiming of the ejectors minimizes the inadvertent rejection of any good product.

Modern optical sorting machines use duplicate image processors so that different types of defect can be identified independently, such as large pale defects and small dark defects (originally used in the rice industry for identifying pale yellow grains and peck, respectively). Figure 3 shows some typical defect classifications found in wheat.



Fig.3 Typical defect categories found in wheat

### Ejection

Defects, whether grains or foreign material, are ejected from the product stream by pulses of compressed air. These pulses are accurately aimed at the unwanted items by nozzles, a compressed air source being connected to the nozzles via a rigid duct and switched on and off by high-speed valves.

The principal objective of a single ejection event is to remove a defective grain whilst minimising the disruption to the trajectory of adjacent good product. The Z-Series machine achieves this with the following component attributes:

Nozzles (see figure 4) -

- Aerodynamically developed to minimise the spatial diffusion of the effective ejection pressure zone and minimise the cross-talk between adjacent nozzles whilst maintaining the ability to reject all defect particles.

- Pitch suitable for bulk and channelled sorting.

Ducts -

- Rigid ducts reduce pulse energy absorption.

Valves (see figure 5) -

- High speed
- Repeatable operation
- Long life
- Low manufacturing cost
- Serviceable



Fig.4 Nozzles (note the pulse profiles of the air blast protruding out of some of the nozzles.)

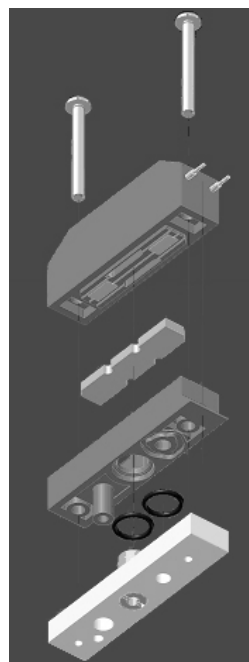


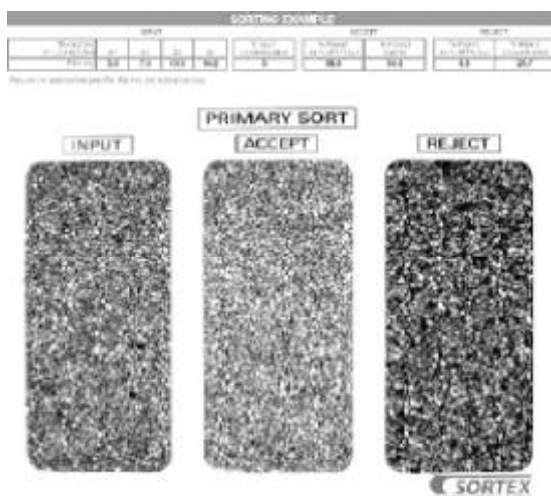
Fig.5 Ejector Valve (exploded view)

### Results

Figure 6 shows the performance of the Z-Series for sorting buckwheat in a single pass through the machine. Note that in an actual installation in a mill the reject would be resorted on a channelled chute to reclaim the majority of the falsely rejected good product.

### Conclusions and future work

In this paper, we have described recent improvements in the design of optical sorting machines that have led to a step change improvement in performance. These improvements include wider chutes for greater throughput, higher camera resolution and more sophisticated image processing for better detection of defects, and a new ejector design for increased ejection efficiency. The resulting increase in performance has enabled wheat mills in Western Europe to use



(The Z1, Z2, Z3 and Z4 throughput values refer to the different size options of the Z-Series, where the number refers to the number of modules, for example the Z-Series in figure 1 is a Z4.)

Fig.6 Results from the primary sort of buckwheat using the Z-Series

optical sorting machines in place of mechanical cleaning equipment.

The use of optical sorting machines in wheat milling

has been achieved by a transfer of technology from rice to wheat milling. There may be a case for a similar technology transfer from the vegetable industry. In the vegetable industry, optical sorting machines include specialized electronic hardware for sorting by shape and size as well as colour. We are currently exploring the possibilities for using similar specialized hardware for shape & size sorting of wheat.

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