

# On-line bed thickness measurement of self clearing continuous centrifuge using laser application

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## abstract

The Self Clearing Continuous Centrifuges (SCCC) are mainly used in sugar factories for the separation of sugar crystals from molasses. Variation of bed thickness in a SCCC is expected to play an important role in the quality of sugar crystals. However since baskets are normally rotating at a speed of more than 1000 rpm, measuring the bed thickness is a difficult task which is tackled as a part of this research. This paper describes and discusses the design and development of an optical method based on laser technology application to measure the bed thickness on-line on a (SCCC) which does not interfere with flow behavior in the basket.

Keywords: centrifuge, laser application, molasses separation, sugar crystal, thickness

## Medición en línea mediante láser del espesor de lecho en una centrifuga continua autolimpiante

Las Centrifugas Continuas Autolimpiantes (SCCC) se usan principalmente en los ingenios azucareros para la separación de los cristales de azúcar de la melaza. Puede esperarse que la variación del espesor del lecho en una SCCC juegue un papel importante en la calidad de los cristales de azúcar. No obstante, dado que las canastas están girando normalmente a una velocidad superior a las 1000 rpm, la medición del espesor del lecho es una tarea difícil que se aborda como parte de esta investigación. Este trabajo describe y analiza el diseño y desarrollo de un método óptico basado sobre la aplicación de tecnología láser para medir en línea el espesor del lecho en una SCCC que no interfiere con el comportamiento del flujo en la canasta.

## On-line Messung der Bett Dicke von selbst reinigenden Zentrifugen mittels Laseranwendung

Selbst reinigende kontinuierliche Zentrifugen (SCCC) werden in Zuckerfabriken vorwiegend zur Separation der Zuckerkristalle von der Melasse eingesetzt. Es ist anzunehmen, dass Variationen der Bett Dicke in einer SCCC eine wichtige Rolle bei der Qualität der Zuckerkristalle spielen. Da sich die Körbe jedoch normalerweise mit einer Geschwindigkeit von über 1000 rpm drehen, ist die Messung der Bett Dicke eine schwierige Aufgabe, die im Rahmen dieser Forschungsarbeit in Angriff genommen wurde. Dieses Paper beschreibt und diskutiert das Design und die Entwicklung einer auf einer Lasertechnologianwendung beruhenden optischen Methode zur on-line Messung der Bett Dicke in einer SCCC, die nicht in das Flussverhalten im Korb eingreift.

## Medição online da espessura do leito da centrífuga contínua de auto compensação usando uma aplicação a laser

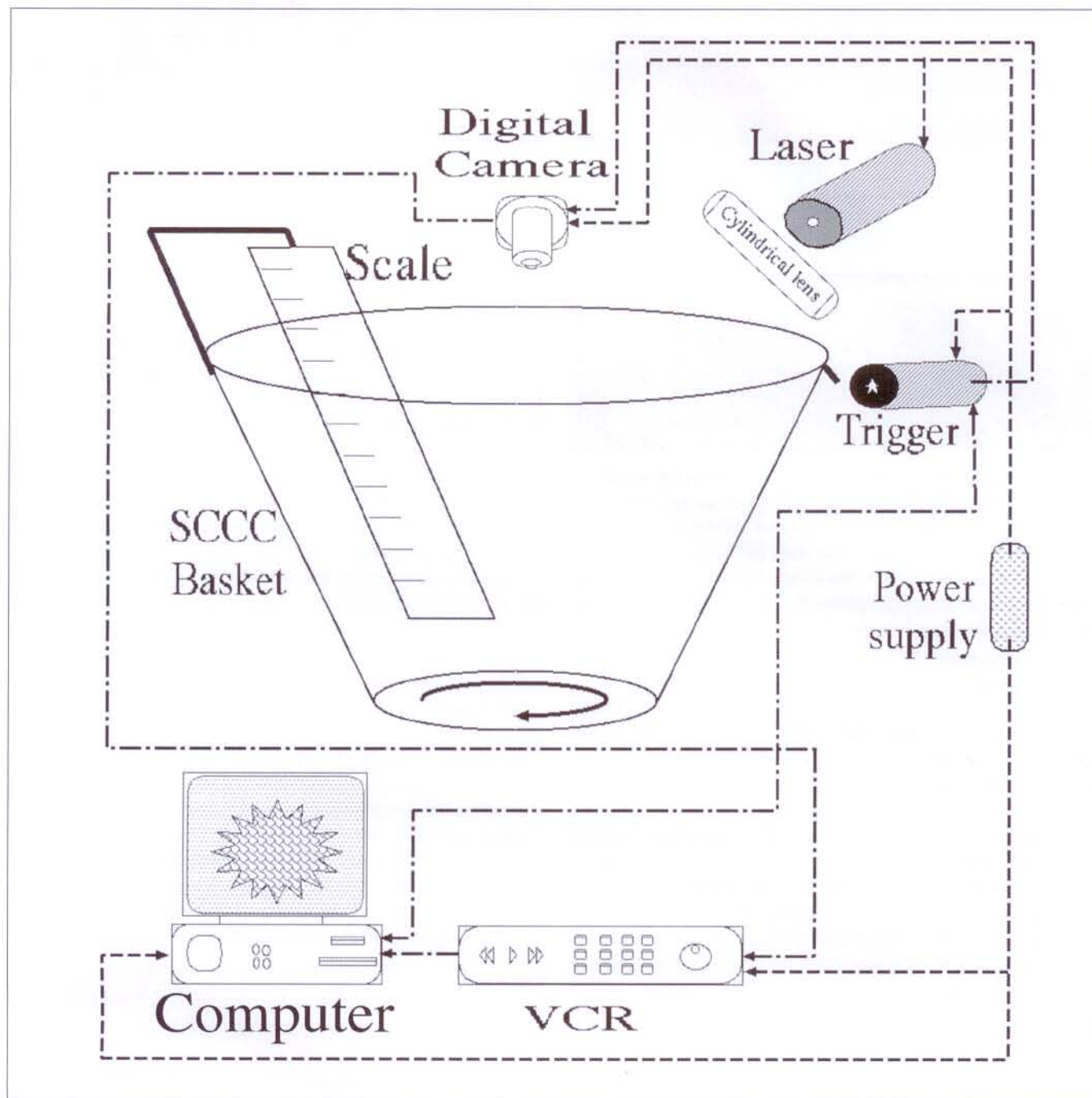
As centrífugas contínuas de auto compensação (SCCC – do inglês, Self Clearing Continuous Centrifuges) são usadas principalmente nas fábricas de açúcar para a separação dos cristais de açúcar do melaço. Contudo, como as cestas normalmente giram a uma velocidade de mais de 1000 rpm a medição da espessura do leito é uma tarefa difícil, e ela é tratada como parte desta pesquisa. Este artigo descreve e discute o projeto e desenvolvimento de um método ótico baseado na aplicação da tecnologia a laser para medição online da espessura do leito em uma SCCC que não interfere com o comportamento do fluxo na cesta.

## Introduction

The sugar production process is extremely complex, involving many different stages. One of the most important of these is the separation of sugar. The majority of the world's sugar is produced by what is commonly referred to as a 'Three Pan Boiling System', although it is rare to find the system being used without some kind of modi-

fication. Each of the three systems comprises a boiling pan, a receiver/crystallizer and a battery of centrifuges.<sup>1</sup> A centrifuge separates particles from liquids by centrifugal force in much the same way a settling tank separates particles by gravitational force. The variables affecting centrifuge performance can be classified as: operating variables and design variables. Operating variables determine the difficulty of the separation task. They include particle size,



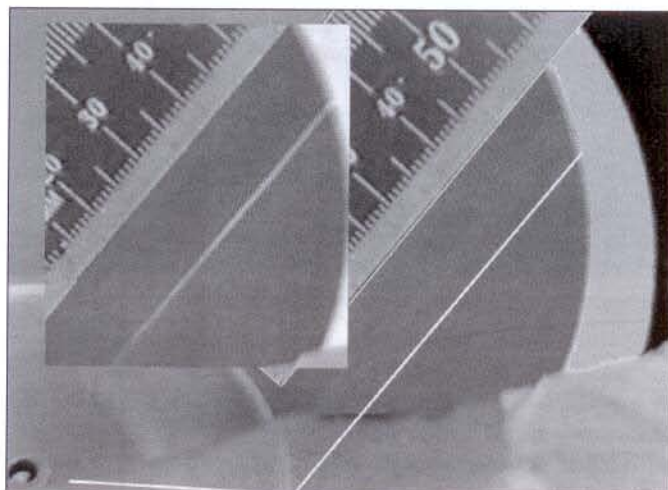
**Figure 1.** Setup for on-line bed thickness measurement in a SCCC

flow rate, fluid/particle density differential and fluid viscosity. The design variables that determine the separation capability of a centrifuge are rotational speed, effective bowl radius and bowl height. These variables affect residence time or centrifugal force.<sup>2</sup> Modern sugar factories mainly use the Self Clearing Continuous Centrifuges (SCCC) for the separation of sugar crystals from molasses. The thickness variation of the bed at different points in a SCCC is a function of basket speed, basket angle, basket diameter, particle residence time and throughput.<sup>3</sup> Moreover, it is also observed that addition of wash water has an immediate effect on removal of the particles from the basket which affects the thickness of the bed in the basket. Then from previous reported experience of SCCC<sup>4-12</sup> it can be concluded that each of the above has an effect on purity of

the product. Ishida *et al.*<sup>13</sup> proposed the optical method for directly measuring the thickness of a thin transparent film by means of multi-wave laser interference at many incident angles, and was confirmed experimentally by means of equipment made on an experimental basis. The system was available in off-line measurement; about 2 min were required for one measurement. The use of mass forces in the centrifugal field for the separation processes leads to specific advantages and disadvantages in comparison to competing separation processes using the same or other physical separation principles and other forces. An undesired but not avoidable consequence of acting mass forces in sediments of centrifuges is the remaining concentration profile at the bottom. These layers are highly compressed whereas the surface layer of the sediment



**Figure 2.** Reference picture from the empty SCCC. The insert shows the original image, while in the larger picture, the interface has been enhanced



remains very loosely packed. To avoid solid transport problems decanter centrifuges with special designed sludge discharge systems have been developed.<sup>14</sup> Now since thickness is a function of variables, which are considered to affect the purity changes of the product, the significance of this single variable, i.e. thickness becomes more obvious in controlling the final purity of the product. For this reason on-line information about the bed thickness in the SCCC is considered to be an important tool for better SCCC performance.

However, so far the only report cited is the work done by Greig,<sup>4</sup> which attempted to measure the bed thickness during the actual operation of a SCCC. Greig inserted razor blades into the screen and then used a 10X long focal length microscope to examine the height of the layer around the razor markers. A stroboscope was also used to freeze the basket rotation so that each marker could be viewed.<sup>4</sup> Using this technique involves a risk of blades escaping from the basket. The method also had some inherent inaccuracies since the blades disrupt the flow resulting in higher localised bed thickness in the vicinity of the blades. The aim for the new design is to provide a means of continuous bed thickness measurement which does not interfere with flow behaviour in the basket.

### Design specification

In order to study on-line bed thickness measurement of self clearing continuous centrifuges an experimental set-up was designed and constructed (figure 1). In addition to a SCCC, the experimental set-up consisted of a several additional equipment sections required for this design including a digital camera with complete control on its framing speed (number of frames per second) and on its high shutter speed and a fast trigger device which can send an electronic signal to the camera (as well as a computer) for each basket revolution. A laser beam generator with a cylindrical lens was used to convert the single circular laser beam to a thin flat plane of laser light. The experimental setup was equipped with a scale (stainless steel) and a computer with a data logging interface, a fast image grabber card and software and a video recorder to record the operation for later analysis of the data produced.

Figure 1 shows the experimental setup for on-line measurement

of the bed thickness on a SCCC. The steel scale is attached to the SCCC basket at an angle similar to the SCCC's basket half angle. Therefore, it will be parallel along its length with the basket. However, for clearer video picture recording, the scale's width should be tilted at an angle 60° to the basket.

### Operation procedure

The experimental procedure is described through following steps:

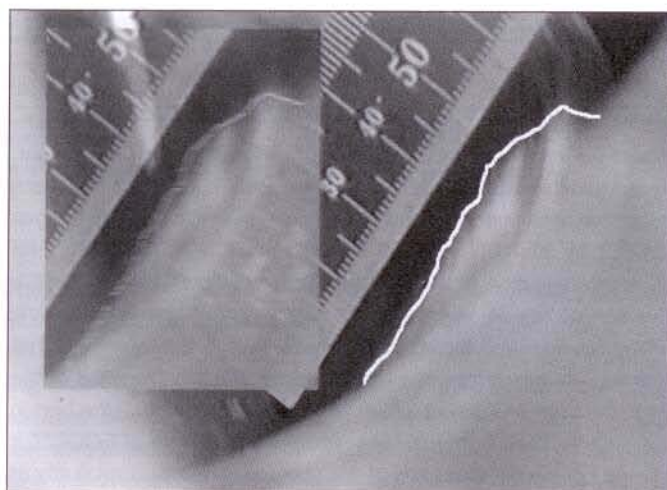
1. The laser light passes through a cylindrical lens and forms a thin plane of light.
2. By adjusting the cylindrical lens angle, a thin plane beam of light will appear on the basket.
3. The trigger device should be adjusted in such a way that on each revolution of the basket, the laser beam formed on the basket is at its closest position to the scale edge and a signal is sent to the camera as well as the computer.
4. To freeze the basket revolution, only one picture per basket revolution is required. Therefore as soon as the camera receives the signal from the trigger, it should take one picture from the scene and pass it to the computer as well as the video recorder.
5. Initially when the basket is empty, a reference picture is taken and saved on the computer.
6. Then as feed is fed into the basket every picture should be compared with the reference picture using the image analysing software to determine bed thickness all along the basket.

Before starting any experiment, it is important that the basket is balanced (aligned) to minimize vibration and avoid other hazards which might occur.

### Test results

For testing, the design shown in figure 1 was simplified to match the available resources. Instead of attaching the scale to the basket, it was fixed in a stationary position using a stand. Using a normal video camera with standard 25 frames per second, the operation was recorded. Using this camera it was not possible to capture the moving bed picture while freezing the SCCC's rotational movement.

**Figure 3.** Experimental result during the SCCC separation process. The insert shows the original image, while in the larger picture, the interface has been enhanced





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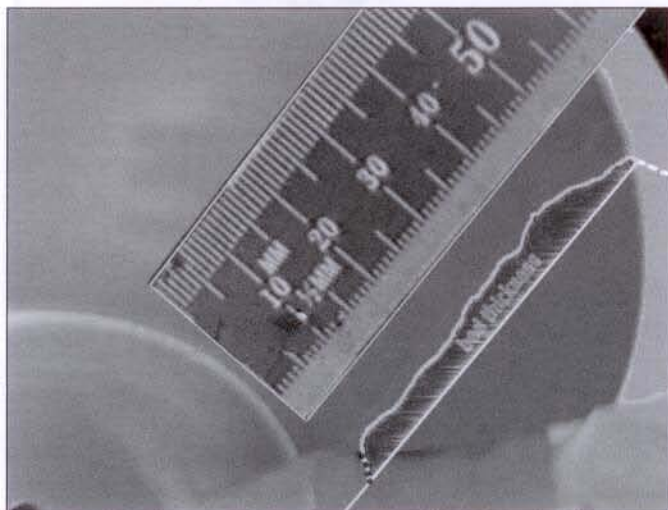
  
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**Figure 4.** Comparison of the SCCC reference picture with the separation process



Moreover, since the SCCC basket was not balanced and feed was not distributed uniformly, the vibration in the basket was obvious. Therefore vibration becomes the main source of inaccuracy and error. The vibration was due to non-uniformity of feed distribution inside the basket as a function of time. Considering the outlet tip of the basket, the vibration (horizontal movement) in a single direction was measured to be up to 14mm in some moments of time. However, to illustrate the practicability of the experiment, Figure 2 and 3 are extracted from among 6000 frames of pictures which were stored in a video tape.

Figure 2 shows the empty basket. This is the reference for comparison with later images. The laser beam and steel scale which are required for measurement are clear in this picture.

Figure 3 shows the SCCC basket during the operation. In this figure, the laser beam does not form a straight line, but changes shape as the bed thickness over the basket changes.

Figure 4 shows a cross comparison of figure 2 with respect to figure 3. The distance between two laser beams is the bed thickness. Though, the same parameter was previously mathematically modeled by Swindell<sup>9</sup> to be about 2mm but the online bed thickness measurement on the upper side of the basket (stick-slip flow region) shows a variation between 6 to 12 mm. Non-uniform variation of bed thickness is mainly due to non-uniform feed distribution. Non uniform feed distribution is also one of the major sources of stress on the main driving shaft. By application of the technique explained in current paper, different types of feed distributors in a SCCC can be well examined. More over this technique in combination with some other techniques such as on-line sampling can be a powerful tool for better understanding of flow behavior in a SCCC.

#### Problems encountered

1. Getting uniform feed is one of the major problems encountered in this technique which causes vibration in the basket and hence erroneous measurement.

2. It is necessary to have control on the frame rates of the camera, which is not accessible with usual cameras available in the market.

3. Variation in voltage is another problem which may causes the variation in basket rpm.

4. Adjustment of the semi-cylindrical lens to is very important to get a narrow laser line on the basket.

5. When surrounding environmental lighting is not suitable, it may not be possible to grab useful pictures for further image processing.

#### Conclusion

A challenge for the centrifuge design engineers and machine drive system, as well as complying with more and more stringent specifications, is ensuring that the sugar factories have the most comprehensive centrifuge system at their disposal. An optical method for measuring the bed thickness online on a SCCC which does not interfere with flow behavior in the basket was designed and developed.

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