A study on early detection of sewer pipeline blockage using CCD tomography approach

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Abstract. In a sewage system, congealed mass is created by mixing non-biodegradable solid matter with fat, oil and grease. Congealed mass might cause a sewer blockage and overflow. This issue may impose a risk to public health and environment. It also leads to increased operational and maintenance costs of sewer system. A robust and durable sensor system are required to monitor the sewer network blockage which could cause a fluctuation in the data. CCD tomography approach will be used to detect the congealed mass forming in sewer network at early stage. The main concept of CCD tomography approach is to analyze the structure and composition of congealed mass by examining the light intensity after penetrated. Therefore, the location and size of the sewer blockage can be predicted. Light reflection from the congealed mass will strikes onto CCD surfaces. This light source will be converted into an electrical signal which is in voltage output value. Filtered images of Linear Back Projection (LBP) algorithm will be applied to reconstruct the image and identify the characteristic of congealed mass either fat, oil or grease. The location and the size of the congealed mass forming also can be identified using this CCD tomography approach.

1. Introduction

The fundamental concept of a tomography system is to identify the distribution of objects by obtaining data through sensors distributed around a pipeline or vessel system 's periphery [1]. The purpose of a mathematical algorithm software tomographic imaging system is to evaluate the concentration, velocity, mass flow rate, and distribution of particle size by measuring them with waves or radiation [2]. Three main components of tomography creation are available: hardware, data acquisition system, and software [3]. Until the information is sent to the computer, sensor signals are usually amplified, filtered and multiplexed [5]. It is possible to run process tomography offline, online or both. Data capture and data processing time should be quick for an online system [6].

Industries, such as wastewater disposal, need a measuring device for gas or solid detectors. One of the popular tomography methods used in the medical and process industries [7,8] is the optical tomography system (OPT). The OPT system is known to be a hard-field sensor, because the sensing

field is based on radiation attenuation or absorption measurements [9]. Generally, the key principle of OPT is to examine object structure and composition by analysing the structure and composition of objects [2]. The basic principle of the OPT is based on the interaction between light and particles, so the reading of the composition, structure and location is given by this interaction. Information on the absorption and/or emission of light from the material is necessary to examine as this is the type of data researchers need to track for measurement of solid, fluid, and gas composition or molecular structure. Typically the high visual absorption of an object, such as a solid material, is known as a translucent object, such as frosted glass [2], for the purpose of allowing light to penetrate [2].

The increasing number of congealed mass in sewer pipeline network will form a blockaded. As a result, it will force the surrounding liquid to the sides of the pipe wells and damage the system of the sewer network. Sadly, the flow pressure would be influenced by this. Continuous sewer pipeline system control is therefore very critical. For monitoring control, the liquid flow rate and blockage location in the liquid medium are mandatory details. The best approach is OPT, because it consists of hard field sensors [9] where the sensor does not rely on conductivity changes or allowance changes for the subjects to be tested. There is a good resolution in the OPT system in which a very detailed image can be captured without the pixels being visualised. OPT also has a high-speed system to capture data and is suitable for applications with real-time monitoring schemes.

2. Research methodology

Another technique proposed by recent OPT scientists is Charge-Coupled Device (CCD). The sensor of this sort is extremely sensitive to dark areas. A CCD line or array can deliver high data resolution is the special feature of this sensor. Semiconductors for complementary metal oxide (CMOSs) come from the same CCD sensor family. The built-in analogue to digital converter part [10, 11], is the difference between CMOS and CCD. The image resolution created by CCDs is better than CMOS because it allows CMOS architectures to add more circuits, which will produce more noise for image reconstruction.

A combination of CCD and laser is the best because for two-dimensional image measurement, CCD has high precision, while the laser in the axial direction has high precision [12]. The combination helps to develop instruments for thickness detection that give high sensitivity, precise accuracy and high reading distance stability. These situations show that the best transceivers for measurement technologies are CCDs and laser diodes. Compared with other opto-electronic sensors, such as photodiodes and phototransistors, this type of sensor has different requirements. When finding a black spot, the CCD's voltage output will be increased to a maximum of 5 V.

The simulation of the optical system consists of two subsections: study of the transmitter and receiver simulation. In this research, the light scattering and light diffraction effects are insignificant, as the diameter of the target under study is greater than the wavelength of the laser diode [2]. In order to cancel small light diffraction effects, measurements of the voltage performance of CCD sensors need to be averaged. For monochromatic light sources such as lasers, light dispersion would not occur [13]. As a result, in this OPT method, only two light parameters are considered, namely light absorption and light reflectance effects.

In the same plane, a combination of rectilinear and orthogonal projection creates an octagonal shape for the orientation of sensors. In image reconstruction, a high number of projections will decrease the smearing effect [14]. There are 2048 pixels in the Sony ILX551A and the resolution is 14 μm x 14 μm. The total length of its sensitive pixels is 28.6720 mm equivalent. This analysis utilised a pipeline with a diameter of 100 mm. In figure 1, the OPT unit and its dimensions are illustrated.
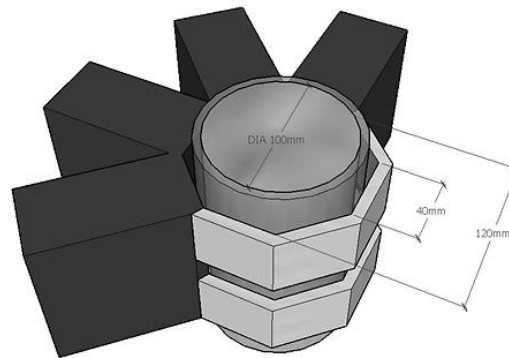
Figure 1. The OPT system and its dimension.

A cross-sectional view and a side-view of the pipeline and OPT system are shown in figure 2. The images show the OPT system arrangement of the upper and lower planes. It shows that the distance is equal to 30 mm between CCD 1 and CCD 5. To prevent the misalignment of data flow, a small distance is needed by the system.
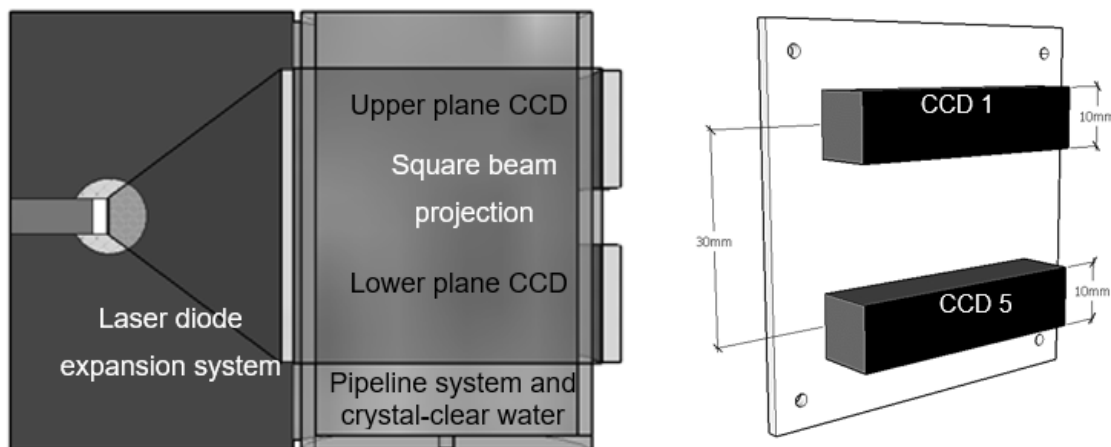

Figure 2. Illustration of cross-sectional view and side-view image of pipeline and OPT system.

3. Tomogram reconstruction

Image reconstruction is also known as tomographic reconstruction in the field of tomography. Analyses on the image reconstruction algorithms are required to get a high resolution of tomogram reconstruction. Optical properties such as light reflectance, light reflection and light intensity are involved in the investigation of the CCD and laser diode OPT system. The relationship between the CCD output voltage values and the laser intensity ratio in the OPT system defined is shown in table 1 when the lasers are in operational or off mode [15].

Table 1. CCD voltage output value and laser intensity ratio in operational or off mode [15].

Laser Condition	CCD Voltage Output (V)	Light Intensity Ratio
Off	4.7419	0
On	1.8142	0.6435

The output of the CCD voltage and the laser's intensity ratio are directly proportional. Figure 3 displays the CCD voltage output interpolation graph versus the laser intensity ratio. From the interpolation graph, it can be inferred that the CCD voltage output is inversely proportional to the intensity ratio of the laser gradient of -4.5497 and the interception value of 4.7419 at zero voltage [15].
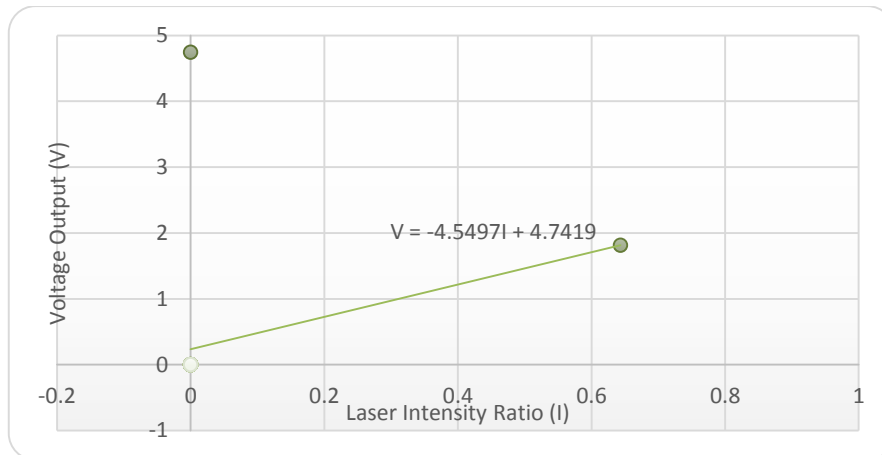

Figure 3. CCD voltage output (V) interpolation graph versus laser intensity ratio (I) [15].

This image reconstruction study uses a combination of Linear Back Projection (LBP) algorithms and threshold values [16]. The equations used are demonstrated below:

$$V_{LBP+threshold(160\ views)}(x,y) = \sum_{tx=0}^{159}\sum_{rx=0}^{159} S_{tx,rx}\ xM_{tx,rx} \tag{1}$$

$$V_{LBP+threshold(160\ views)}(x,y) = \sum_{tx=0}^{319}\sum_{rx=0}^{319} S_{tx,rx}\ xM_{tx,rx} \tag{2}$$

where $S_{tx,rx}$ refers to V_{CCD} and $M_{tx,rx}$ refers to sensitivity map. Another stage of image reconstruction enhancement is added to minimise the smearing effect that still exists due to the combination of LBP and threshold image reconstruction. The filtered images are the result of comparing the image analysed with an initial image phase in which the method does not have a congealed mass.

The outcome of previous studies on the identification of solid and transparent objects will be used as the basis for this early analysis. Solid and translucent objects will be interpreted as a congealed mass for the experiments. Through the pipeline structure, it will be dropped. Such tests are performed to verify the ability of the CCD OPT device to detect and capture the image of these congealed masses in a water-filled pipeline. It can capture image reconstructions of the congealed mass in water.

Table 2 and table 3 examine the two-dimensional cross-sectional images that are present in the pipeline system of two items that vary in opacity, diameter and position. The appearances of foreign objects are highlighted with a higher contrast colour, which is dark orange in this table, for LBP image reconstruction. The filtered image reconstruction is shown in table 3, where only the presence of a solid and transparent object is highlighted to provide correct details on the object's size and location.

In the LBP process, for a solid object, the 160-view image reconstruction has z-values between 1008- and 1072-pixel values. The z-value is calculated from 1008 to 1040-pixel values for the translucent object. The solid object has an overall z-value of 210-pixel values in the 160 filtered image reconstruction views. The overall z-value for a translucent mass is 167-pixel [17]. During the same time scan, the combination of LBP and filtered image reconstruction shows that this OPT device can detect solid or translucent artefacts in a liquid flow. The reconstruction of the picture reveals the location of the object on the left side of the pipeline. The likelihood of a sewer pipeline system being blocked by a congealed mass is critical for monitoring both data.

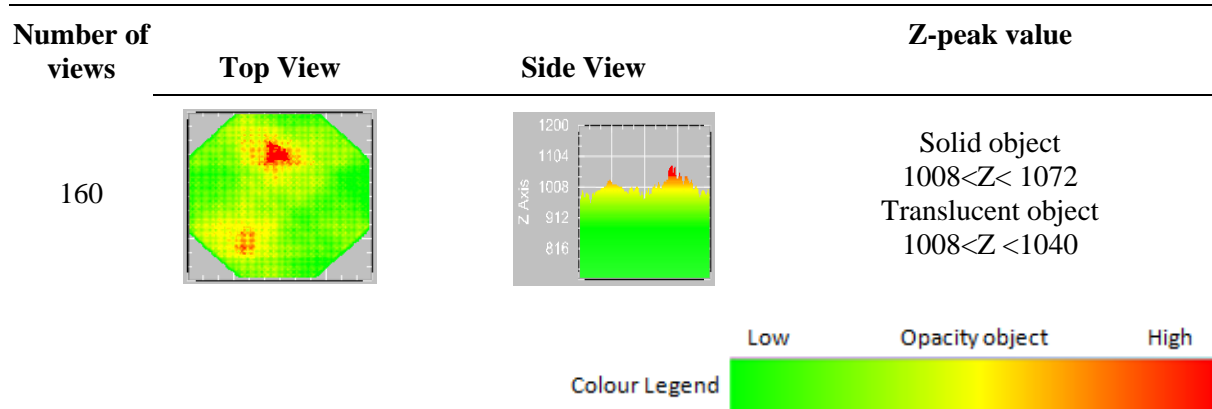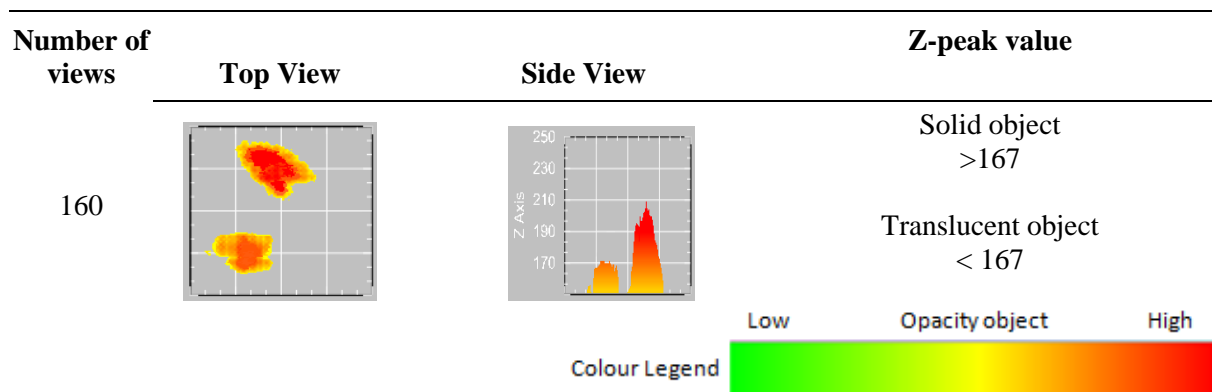**Table 2.** LBP image reconstruction for congealed mass in the same time scan [17].

Number of views	Top View	Side View	Z-peak value
160			Solid object 1008<Z< 1072 Translucent object 1008<Z <1040

Table 3. Filtered image reconstruction analysis for congealed in the same time scan [17].

Number of views	Top View	Side View	Z-peak value
160			Solid object >167 Translucent object < 167

4. Conclusions
The outcome of this research is the early detection of congealed mass blockage using the CCD tomography method in the sewer pipeline network. The OPT system, consisting of a laser and CCD as its transmitter and receiver, is believed to be able to calculate the characteristics of the congealed mass in the sewer pipeline system and to reconstruct its cross-sectional images. It is possible to distinguish details like the location and the extent of the blockage. Since no probes or sensors need to be mounted in the sewer pipeline system, due to the absence of any intervention in the monitoring processes, this system provides more reliable results. This early detection alert will help local authorities implement the construction of congealed mass traps to minimise the risk of the development of fatbergs, which would have a negative effect on health, the atmosphere, the economy and society.

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