Technical Note

TN 5.08 Laser Profiling of Flexible Pipe

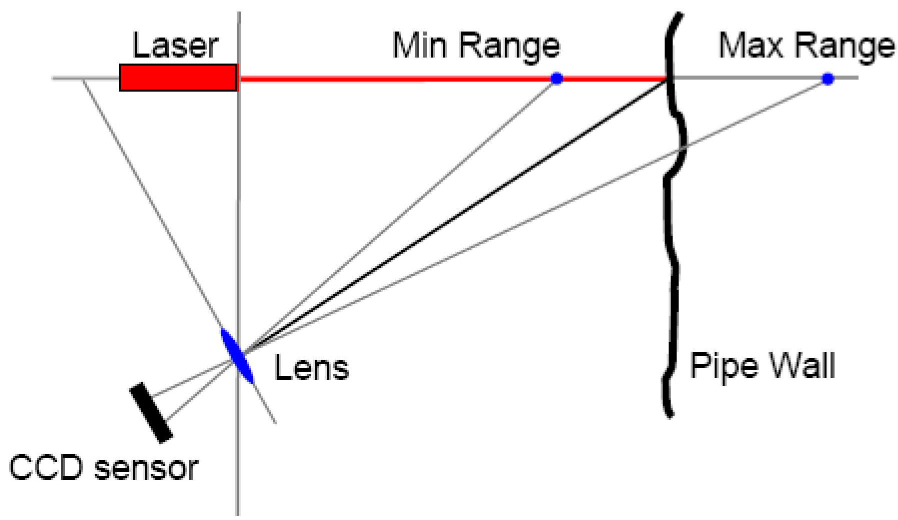
Introduction

Historically, the use of closed-circuit television (CCTV) inspection technologies has been a common method to provide post installation inspection of various pipe types. This technology can provide a qualitative analysis of the interior of a pipeline, but it can be limited due to the subjective nature of the visual assessment process. Laser profiling, which was originally developed for the thermoplastic Cured in Place Pipe industry, is a new technology that can provide precise measurements of pipe parameters. However, there are some current limitations with the technology that can lead to sporadic and erroneous results. Additionally, the limitations can lead to precise but inaccurate results. The purpose of this Technical Note is to provide a discussion of the current state of the technology.

Laser Profiling Description

Laser profiling is a non-contact inspection method used to determine a pipe-wall profile. The method uses a machine vision technique known as optical triangulation as shown in Figure 1. This involves projecting a laser onto the interior surface of the pipe, and an image of this light spot is then formed on a sensor, usually a digital camera. By knowing the position of the laser with respect to the camera and establishing which part of the sensor the light spot is viewed through, one can find the exact location of the pipe wall with respect to the laser and camera. The radial distance data for several positions along the pipe is compiled and plotted yielding a three dimensional wireframe image of the pipe.[1]

Figure 1
Optical Triangulation Geometry



Position and Orientation Tracking

The primary difficulty with the use of laser profile equipment is tracking the position and orientation of the equipment that is used. Absolute positioning systems could be employed that correlate the position of the equipment to an external landmark but these are difficult to implement. The more common method to account for position and orientation tracking is with the use of a relative positioning device such as gyroscopes or inclinometer. However, this type of positioning tracking system can be susceptible to many errors.

Gyroscopes use the earth as reference point. In doing so, the gyroscope can not distinguish whether the equipment that the laser is situated on or the pipe has changed position. This can lead to errors in ovality readings unless the laser profiling software can distinguish that the equipment has shifted and not the pipe. This problem can materialize in one of two ways. First, the profiling equipment has meandered off of the pipe axis by a certain horizontal angle. This can lead to a false positive result exhibited by excessive horizontal ovality deflection readings in a round pipe. Secondly, the equipment encounters a bump or offset which results in the equipment meandering off of the pipe axis by a certain vertical angle. In this case, this can lead to an erroneous pipe profile exhibited by excessive vertical deflection readings in a round pipe.

Currently, the software programs for laser profiling can not account for meandering of equipment. To help control equipment wander, one system spaces wheels at 120 degrees in the pipe regardless of diameter. This can lead to positive results for pipe diameters that are 24-inch and less. However, this method can have limited success in the inspection of large diameters as the potential for meander greatly increases. This can lead to a false negative result exhibited by excessive horizontal ovality deflection readings in a round pipe. Software programs currently in place are more effective in dealing with bumps and offsets in the pipe. The systems use an inclinometer to take readings which account for vertical inconsistencies in the pipeline and are more successful in limiting false positive results in vertical ovality deflection readings.

Non Ideal Pipe Conditions

In addition to bumps or offsets, the presence of sediment, water and/or other debris can create vertical inconsistencies resulting in a pipe profile illusion inconsistent with the actual pipe profile condition. One known laser profiling system can operate in pipelines that are partially filled with water. The acceptable depth will vary based on the pipe diameter and equipment utilized. The software package that is utilized can recognize the presence of water and correct the profiling data accordingly. However, this is not consistent in the industry. Other systems require operator input to account for water in the pipeline. This operator input can lead to errors with regards to data interpretation and effect repeatability of the results.

The presence of debris is somewhat more complicated. When debris is encountered, the equipment can meander off of the pipe axis by a certain vertical angle. In this case, this can lead to an erroneous pipe profile exhibited by excessive vertical deflection readings in a round pipe. As with water, one laser profiling system can operate in a pipeline that has accumulation that is 10 percent of the pipe diameter. The software package can recognize the presence of the debris and correct the profiling data accordingly. As with water interpretation, this is not consistent in the industry. Other systems require operator input to account for debris in the pipeline. This operator input can lead to errors with regards to data interpretation and effect repeatability of the results.

For the best results, the pipe should be clear of all sediment, debris and water. Otherwise, considerable post-inspection data analysis will be necessary to distinguish whether deflection readings were actual or a false positive created non ideal pipe conditions.

Environmental Factors

The laser profile may be disturbed, impeded or dispersed due to atmospheric density differences relating to fog or dew formation in the pipeline. This can affect the light intensity in the pipeline which in turn will negatively impact the laser profiling process. As mentioned previously, the technology involves projecting a laser onto the interior surface of the pipe, and an image of this light spot is then formed on a sensor, usually a digital camera. If the fog or dew formation is of sufficient intensity, the laser may be reflected and never reach the interior surface of the pipe. This may result in laser scatter which in turn may lead to erroneous readings. For best results, the pipeline to be tested needs to be free of any these environmental conditions.

Calibration

The laser profiling equipment requires calibration for possible distortion prior to use as well as during the inspection process. The calibration process varies dependent upon the system that is selected. One system is calibrated under controlled conditions in a laboratory prior use on a project. The calibration involves the use of proving rings of a known dimension. Furthermore, the calibration is specific to the camera equipment that will be utilized with the laser profiler. Another system conducts calibration in the field which is typically done outdoors at the project site. This field calibration involves the videoing of a rod of known length which is at the same position that the laser head would be. The field calibration is susceptible to environmental factors that may result from the calibration being conducted in a non-controlled environment. This can lead to issues with data interpretation and error and ultimately accurate repeatability of data.

Equipment Limitations

The laser profiling equipment varies between manufacturers. Some of the differences can contribute to inaccurate measurements of the pipe and negatively impact the data. For one technology, the laser is coupled to the laser camera via a metal rod. The placement of the metal rod creates a blind spot at the invert where the laser intersects the bar such that proximately seven percent of the pipe interior is not addressed by the profiling. For the second technology, the pipe is inspected with a low distortion video camera first. A laser projector on a sled is attached to the camera via a chain. The video equipment is pulled backwards towing the laser profile sled and the video camera records the image of the laser. Since the camera and the laser profiler sled are on separate pieces of equipment attached with a chain, they are free to move independently of each other. This process is not only time consuming since two independent reviews of the pipe are done but can also lead to variability in the results. Since the equipment is on two separate frames, the profiling will be based on the relative positions of the equipment which can vary based on speed and the interior of the pipe. Additionally, if there are any obstructions in the line, this will cause one of the two components to react differently than the other, further impacting the ability to achieve reliable results. Operator interpretation of the data can lead to further variability in the results. One method to address this is to have the laser and camera on the same frame which fixes the location of the two and helps to eliminate relational errors.

Data Analysis

Final results from the laser profiling inspection are based on analysis of the data. This is especially applicable for some laser profiling systems where there is debris or water in the line that needs to be accounted for. Analysis can take up to two weeks to complete which may create delays in the overall project schedule. Some systems are attempting to implement a wireless component for data transmission to expedite delivery of information and expedite the overall schedule. However, this will still be project specific. Regardless of the system that is selected, the data analysis and report delivery timeframe needs to be evaluated and compared against the overall project schedule to ensure that excessive delays are avoided.

Summary

The use of laser profiling is a relatively new technology. The technology is extremely interesting and allows for the collection of a large amount of data. However, accurate, repeatable results are limited at this time due to pipe condition, environmental factors, operator interpretation and equipment limitations as discussed above. Although the technology is promising, it is still developing. As a result, the technology is still under evaluation and has not been approved for wide use by any major national approval body.

[1] *Refining Laser Profiling Methods Used for Pipeline Assessment,* Trenchless Technology Center, Louisiana Tech University, Ruston, Louisiana, April, 2005.

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