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PIPE SURFACE INSPECTION BY INDUSTRIAL MACHINE VISION

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Abstract

Metallurgy Industry which mainly transforms the steel or its derivative products into products with either better surface properties or into different shape products involves some processing tools which can often generate flaws within the process.

The primary goal of this prototype is to provide a view of the whole surface of the pipe to the operator when the surface of the pipe is completely machined. Various lighting systems where tested so as to reveal the maximum number of defects such as tool marks, scratches, etc. The pipe surface being not smooth (rough), we found that a homogenous lighting (diffused) of the scene enabled a clear inspection of the tube surface and reveal most of the defects.

We have taken nickel pipes which are used for oil prospecting and deep earth applications and using our optics along with machine vision camera we devised suitable software so that the inspection of the pipe surface is carried out on tool – inspect – tool basis. Since the tool contact area on the pipe surface is one square milli meter we divide the image of the pipe surface into several templates and analyze for flaws such as micro dints, micro lamination or micro fissure. The difficulties in real time image acquisition and analysis are thoroughly studied and overcome. The software has all options for image enhancement, analysis, measurement and also statistical process control options.

Key words: Pipe Surface, Machine Vision, Image processing

Introduction

This paper deals with a machine vision system design to control and inspect the outer part as well as the inner part of nickel pipes for oil wells. These pipes are made from zirconium alloys or Nickel. During the manufacturing process various defects can be generated (grooves, tool marks, pulling out, scratches….), these defects can deteriorate the pipe quality and have therefore to be detected. Prior to this study, the only visual inspection was done by the operators. The pipes were inspected through a simple magnifying glass and according to their one judgment; the operator "grade" the defects: a code 1 means a sound tube whereas a code 4 leads to a complete stop of the production. Manual control tasks being fastidious and subjective, a machine vision system was developed to help the operator during his inspection task.[1]

In order to develop this system various lighting conditions were tested and the resulting images shown to the operators. After a survey involving all the operators (day-shift and night-shift operators) two configurations were selected. The first part of the article rapidly summarizes the procedures for the selection of the lighting systems. The second part of this article presents some of the image processing tools used to detect some of the defects. The last part outlines our future work which will consists in investigating other image processing tools as well as in using a classifier to sort out the different defects and end up with an autonomous machine vision system.[2,4]

Lighting systems

Requirements

The exact pipe dimensions and surface of interest are as follows.

The length of the pipe = 4.5 meters

Inner Diameter varies from 75 mm to 200 mm

Outer Diameter varies from 100 mm to 250 mm

Pipe has to be tested for flaws at both inside and outside

The experimental optics and its characteristics are as follows

The Field of View = 1.5 square millimeter

The working distance is adjustable from 5 to 50 millimeter

Magnification by optics alone 100X and can be increased upto 500X by changing the objective alone

Size of the optics is 3cm X 5cm X 2 cm in dimension

The Tool dimensions are as follows

The tool contact area on the surface of the pipe is roughly around one square millimeter

The time taken to tool the entire pipe is as follows

Time taken to tool the entire pipe may be from 7 to 8 hours depending upon the skill of the machinist

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Sometimes, the pipes can be longitudinally sliced so as to inspect the inner part of it. Therefore the system has to be fairly versatile so as to be able to inspect inner part and exterior part of pipes of different diameters. On these pipes, many different flaws have to be seen and detected (scratches, pulling-off, grooves, corrosion spikes, tools mark….). In order to see all the defects various lighting conditions have been studied. The next subsection presents the lightings which have been selected.[3]

Lighting system configurations

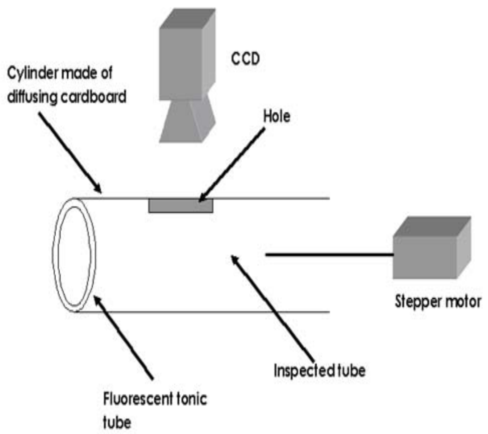
A set, composed of twenty pipes selected by the operators and having the most common encountered flaws, was made.

On this sample set, different lighting conditions were tested. In our application, we have been mainly focusing on a compromise between a diffused and direct lighting. A diffused lighting (ideal for changes of tints, small corrosion marks) reduces the influences of surface texture and avoids specular reflection on metallic surface, while a direct lighting leads to the

best contrast in the case of relief defects (tool marks). All the defects were imaged with our eight predefined lighting conditions, the acquired images were then sent to the operators whom grade them.[3]

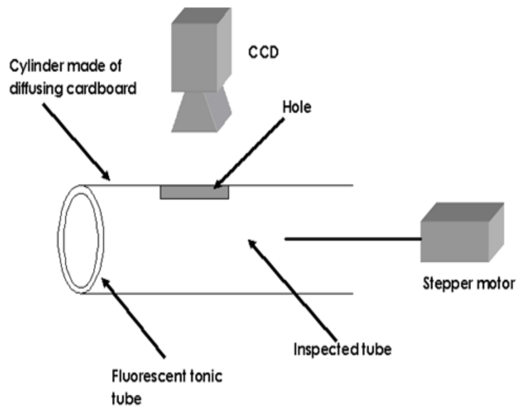
1. Homogenous lighting: The lighting system is made of a fluorescent tube and a diffusing cardboard onto which a hole was punched for the camera to visualize the scene. (Fig. 1)

Fig. 1: Homogenous light



2. Structured lighting: the lighting system is made of 2 fluorescent tubes. In this case, the inspection zone is restricted to the zone delimited by the reflection of the two fluorescent tubes onto the metallic tube.[3] (Fig. 2)

Fig. 2: Structured light

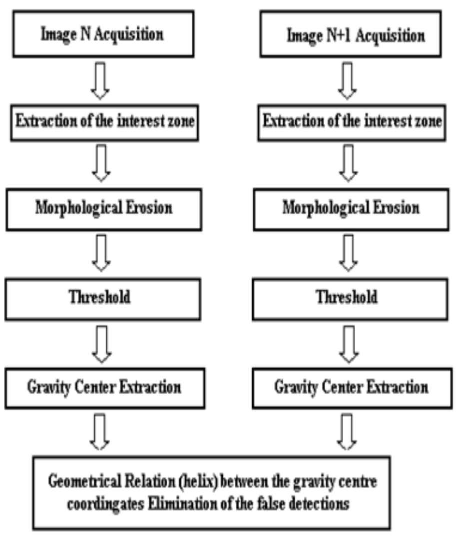


Machine vision prototypes

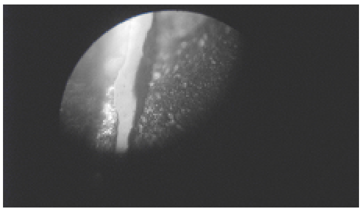
A prototype based on the aforementioned two lighting conditions aimed at helping the operators in their inspection task was developed. The system is composed of 2 full frame CCD cameras of 1.3 mega pixel interfaced to a frame grabber and 3 stepping motors. One stepping motor is to translate the pipe, second is to rotate them and the third one to translate the CCD cameras so as to keep the optic of the camera (focal length, depth of field…) constant whatever the tube diameter is. The tube is firstly inspected under the structured lighting system so as to reveal tool marks, then the tube is automatically moved to the diffused lighting for the other defects to be revealed.[3]

On each lighting system, the different images of the pipe are recorded and presented to the operator. The interface was developed under Visual C++, procedures were written as DLL in Visual C^{++}.

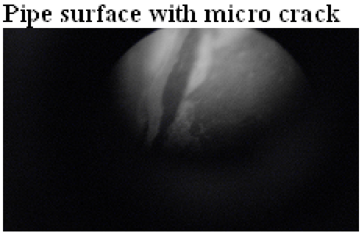
Figure3: Processing step



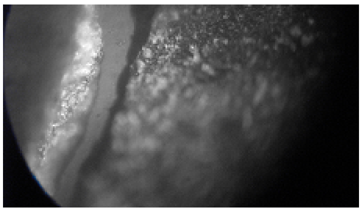
Images of Pipe surface taken by the experimental setup
Photos of Pipe surface with micro crack



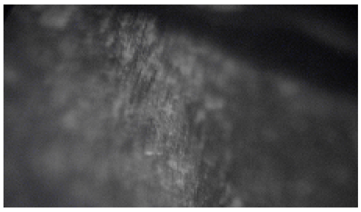
Pipe surface with micro crack



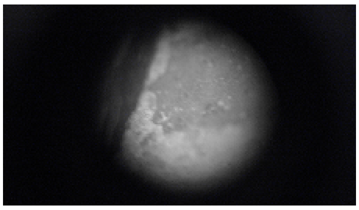
Micro Crack



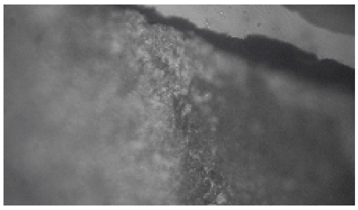
Micro crack



Lamination



Micro Crack



Micro Crack

Conclusion

A machine vision system for the control of metallic pipes was developed. This system is used to help operators during their inspection tasks. Different lighting systems were tested to visualize and detect all the flaws. The whole system is made of 2 different lightings (diffused and directed lightings), 3 stepping motors (to assure tube and camera motions). To this point all the defects are detected. So far, the prototype has been designed to help the operator and should be turned into an autonomous machine vision system in a short time.

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