Non-destructive Evaluation of Material Surfaces Using Laser Scanning System

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Abstract

A reliable, friendly, easy to use portable two dimensional laser scanning system was designed, assembled and used in order to overcome the leakage in some optical NDE in site tests. The system covers range of the wavelengths from 420 nm to1130 nm with 480 µm accuracy. After few limited tests the system showed a promising results for the scan with the possibility of developing a system to obtain more accurate results and a wider range of applications

Keywords: *airborne laser scanning, NDE, Trigonometric triangulation method*

1. Introduction

Trigonometric triangulation method [1] is one of several ways to design laser scanning systems. Despite of the fact that this method has been used for more than twenty years ago, the speed and accuracy have increased dramatically in recent years as a result of the development in the geometric shape of the laser sensors [2, 3].Any laser scanning system can be used to scan any material directly in very short time without coming in contact with the sample (noncontact method) [4, 5]. This property is of a great significance for some characteristics in particular when the sample is a liquid [6].

2. Experimental

The experimental work can be divided into design concept and assembly, system preparation (calibration) and finally some applications.

Design concept and assembly

The design concept in the present study is to convert any optical signal into digital signal to quantify a physical quantity and display it. Practically any laser scanning system can be divided into optical unit and electronic unit and display unit. The optical unit includes three basic elements which are laser source, the probe light and samples under study. The electronic unit includes to be studied, the parts of linking computerized (amplifier signal and digital converter) and the computer analysis the data collection [6]. The optical unit includes:

- A He-Ne laser at 632 nm wavelength used as the light source
- A photo transistor BP-103 (respond in the range between 400 nm to 1130 nm wavelength) is employed as a photo detector.
- The sample holder.

The electronic unit is a computer interface includes

- Lm324 amplifier to magnify the output electric signal.
- AD 570 A/D (analog to digital) converter
- Data acquisition system to connected the system via the output display
- Before the output data was displayed it passes through a digital filter designed in the present work and stored into the computer.
- Software is one of the most critical components, which can give a leading edge to one or another firm, and produce useful information out of a huge amount of raw data. In the present work the software was homemade built using C++ programming language.

A detailed block diagram of the system under use is shown in figure1

System calibration

The first stage after the system was assembled is the system calibration. A clean (dust free) polished (no scratches) standard sample of dimensions 5 cm x 5 cm was installed in sample holder. A laser signal was incident with 45 angle and the reflected signal was received with 45 reflected angle by the photo detector. After the reflected optical signal was received it was converted to analog electric signal, then it was amplified, converted to digital signal and displayed as output data. Both the Laser source and phototransistor move automatically in X–direction. While sample moves automatically in Y – direction.

System applications

The system has been utilized to study some physical applications. These practical applications and discussion of the results are explained below:

Sample of scan (flat mirror)

A flat mirror with a homogeneous composition and dimensions, of 5 cm × 5 cm by the system was designed by moving the panel optical system automatically using Motor Driver which moves rapidly about 20/Sec cm and cuts back on the distance of 40 cm back towards the axis X. After shortening the distance, the sample is moved a step forward by the motor a distance of 5 mm. towards the Y axis as shown in Figure (3). The movement of this engine is controlled by a precise Microcontroller, which has been programmed on the basis of the type of movement required. The system includes. A computer interface (electronic digital circuit) was utilized to convert the electrical signal to digital signal, a computer Software program using C – Language for data analysis. The electrical signal from the sensor is amplified by OP amplifier and then converted to digital signal using A/D converter. Both the Laser source and phototransistor move automatically in X – direction, while sample moves automatically in Y – direction. Both the Laser source and phototransistor moves automatically in X – direction. The sample as well moves automatically in Y – direction. The sensor projector unit linked to computerized, has been build this system is based on the way of trigonometric (Triangulation-Method) where both the laser source and the probe light with the sample make a heads triangle as shown in Figure (2) [4].

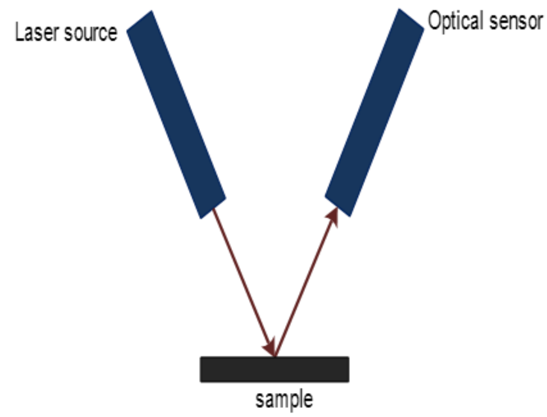

Figure 2, the trigonometric method

Initialize the system to work, a helium - neon laser source was installed on a plastic plate so that it makes the angle of incident beam amount 45° with the vertical (column primarily from the point of falling on the surface of the separation between the air and the sample) are receiving the reflected beam at an angle 45° (according to the law of reflection θr = θi) by phototransistor installed as well as on the plastic plate with a helium - neon laser. One be the phototransistor can move manually by the micrometer to receive the reflections multiple laser beam. Prior to start taking any practical results, one must be sure that the space balance to put the sample as well as poise panel of optical system, are clean samples free of dust accumulation. In addition to the need for some good samples for fine-tuning, some applications do not need the mechanical movement that was controlled in the operation of each part of the system keys run electric as follows:

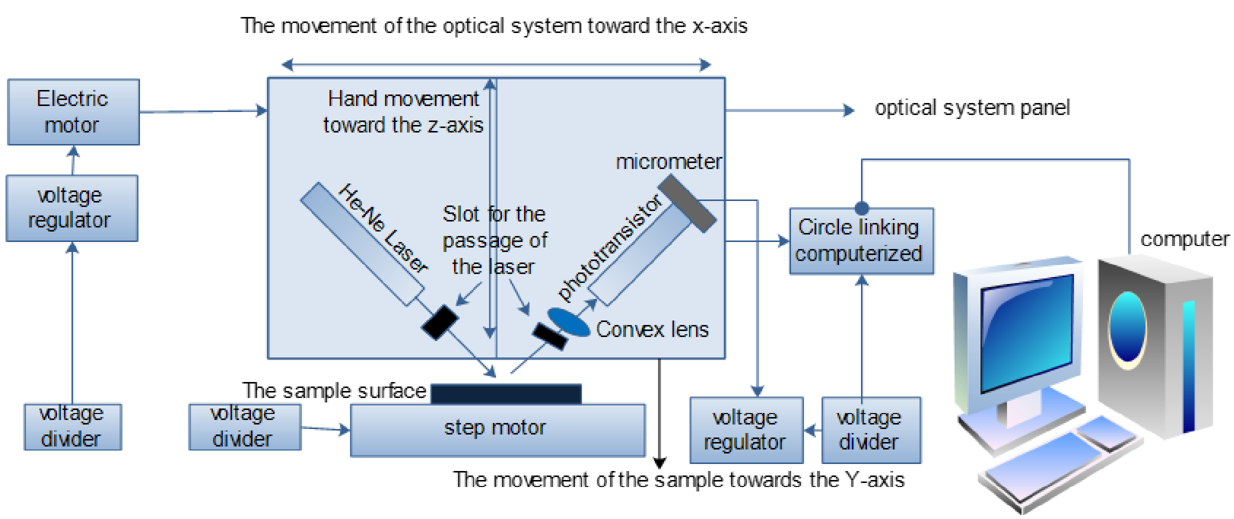

Figure 1, the schematic diagram of the system designed

- A Switch for a helium - neon Laser.
- The key to run the part of the computerized connectivity.
- The key to running a special optical system movement in the direction of the X axis.
- The Key to run a special movement of the sample in the direction of the Y axis.

Repeat this process (the movement of plate syndrome optical system with the movement of the sample) until completely wipe the surface of the sample

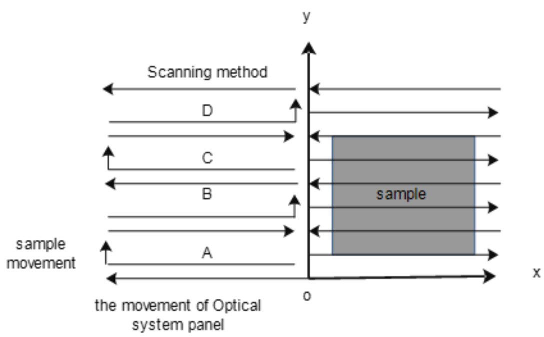

Figure 3, the laser scanning method

3. Results

Reflectivity for the different metals

By polishing the metal surfaces, will refined high reflectivity for general insulators. The experiments show the process that reflectivity does not depend on the type of sample only, but rather on mineral and surface preparation and the wavelength of beam, the incident angle of the fall beam, and the reflectivity of the optical properties of the task of metals, especially in manufacturing industries such as optical devices, resonance lasers, telescopes and interferometer Fabry - Peru [7] . We managed to obtain several pure metals (College of Engineering / University of Tripoli) to study the reflectivity of the laser beam at the surface of all the metal, by refining the surface of each metal using special polishing paper to reach the high-resolution. We noticed the rapid vulnerability of these metals to atmospheric air. When laser beam with intensity (Ii) falls on the metal surface, part of the beam is absorbed inside the material and the other part will be reflected of intensity (Ir). We practically receive the beam reflected by a light sensor (phototransistor BP103), which converts the optical intensity to electrical signal (voltage) with value of ranging from (0 V → 5 V). Turning the electrical signal into a digital signal feeds the computer after it has been magnified by the amplifier signal (LM 324) These certain values fit the effort digital converter user (AD 570). The numerical values are printed on a computer screen using the C language program starting from 0 to 255, each value of these numerical values (Digital Number) corresponds to the value of the effort on phototransistor (Vsen) through the relationship (1) . [8]

$$V_{sen} = \frac{D.Sen}{G} \qquad \text{……………………..(1)}$$

Where : D represents the numerical value indicating that the intensity of the laser beam (no dimensions) which is can be converted into a voltage by equation (1). For example, the numerical value of 255 corresponds with the intensity of 5 V to phototransistor Sen, and represents the sensitivity of the digital converter and is equal to 0.039216 V, G which represents and enlarges the reference value by electrical signal amplifier (LM 324) and equal to 2. to calculated reflectivity R of metal which is the ratio between the intensity of the reflected portion (Ir) and intensity of the fallen (Ii). As : -

$$R = \frac{I_r}{I_i} = \frac{V_r}{V_i} = \frac{D_r}{D_i} \qquad \text{……………..(2)}$$

This application measures the intensity of the laser beam as a numerical value (dimensionless), where Di represents the intensity of the incident beam, Dr Represents the intensity of the reflected beam. Table (1) illustrates the practical values of the reflectivity of different metals.

Table 1 f reflectivity of different metals

R%	D_r	D_i	Metal
44.578	111	249	Steel
32.530	81	249	Developer steel
9.237	23	249	Red Copper
5.622	14	249	Iron
2.811	7.0	249	Brass

Figure (4) illustrates the disparity in the amount of reflectivity between metals .and also confirm the previous findings that replace the optical sensor users by another optical sensor which was borrowed from the Center of Renewable Energies and connect the optical sensor to draw electrical signal. For example we found that the reflectivity Steel Developer equal % 33 supplement [9].

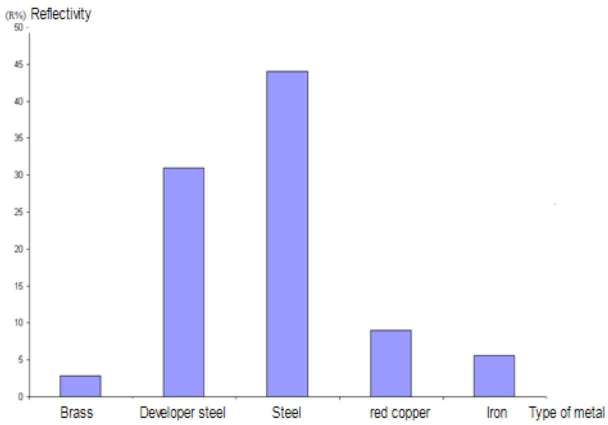

Figure 4 the disparity in the amount of reflectivity between metals listed in the table 1.

Calculation of refractive index of the glass

The refractive index (n) as the quantity of physical describing the properties of optical medium it is the ratio between the speed of light in a vacuum (C) and the speed of light in the medium (V) (n = C / V) and determines what is known as the optical density of the medium [10] .

Figure (5) shown the following processes that occur when the beam collision with the sample: -

* The process of reflection (Reflection) - Based on the law of reflection: the angle of incidence equals the angle of reflection.

* Scattering process (Scattering) - The laser beam is scattered in all directions.

* Depletion Process (Transmission) - The laser beam pass through the material.

* Absorption process (Absorption) - laser beam is absorbed by the material [11].

Equation (3) has been deduced from Figure (6), practically we can determine the refractive index of the medium (n2) by equation (4), which represents the optical path of the two beams output from multiple reflections in the glass mold, and the value of angle refraction θt be substitutes by the equation (5) to get the value of n2

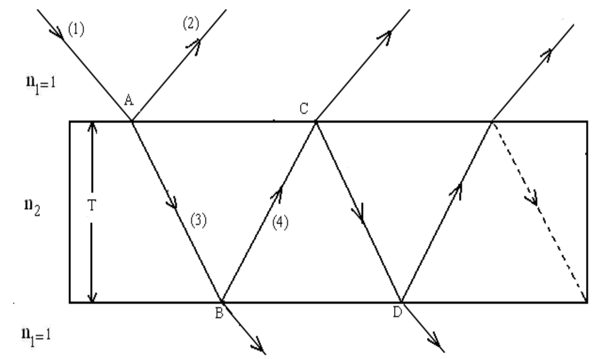

Figure 5, the multiple reflections in the glass template.

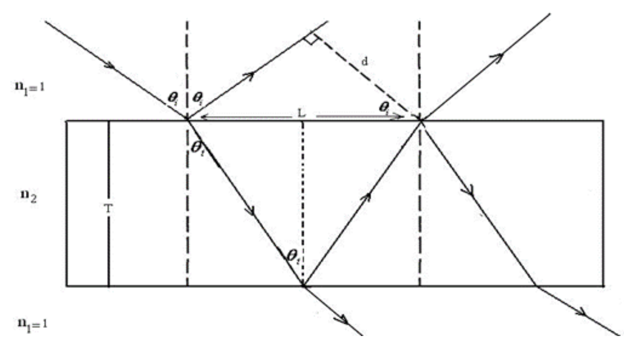

Figure 6 the optical path beams output from multiple reflections in the glass

From Figure (6) we note that

$$\tan \theta_t = \frac{L}{2T} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Where: - compensation from the previous equation we get

$$\theta_t = \tan^{-1} \frac{d}{2T\cos\theta_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

And

$$\frac{n_2}{n_1} = \frac{\sin\theta_i}{\sin\theta_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where : - n1 = 1 (on air) .

The calculation of refractive index of the glass by the laser system can be achieved by dropping the laser beam from air on the surface of the molded glass and also on several flat mirrors with a different thickness and homogeneous visual angle of 45˚. To find the distance between any two reflection consecutive precisely using micrometer manually gives accuracy reading of 0.01 mm Sticky phototransistor are also finding thickness of previous samples using its digital accuracy of 0.01 mm and hence we can calculate the angle of refraction through compensation value of incidence angle θi and the distance between any two reflection consecutive d and thickness T use equation (2). can be calculated therefor the refractive index of the equation (4).

Table 2 practical results to calculate the refractive index of the glass

n_2	θ_t	d [mm]	T [mm]	θ_i	Sample
1.533	27.466°	13.850	18.84	45°	Glass mold
1.594	26.342°	2.780	3.97	45°	Flat mirror
1.628	25.751°	1.760	2.58	45°	Flat mirror
1.496	28.210°	1.100	1.45	45°	Flat mirror

Note: -Taking into account the refractive index as one of the known physical constants can use this application to find thickness of the samples

4. Conclusion

In this paper, a reliable, friendly, easy to use portable laser scanning system was designed and constructed locally in order to overcome the leakage in some NDE in site tests. The system can be used to study the surface contaminations in the industrial plants by measuring some surface properties such as reflectivity of different materials and refractive index. The system covers range of the wavelengths from 420 nm to1130 nm and the resolution was 480 µm. After few limited tests the system gave a promising results for the scan with the possibility of developing a system to obtain more accurate results and a wider range of applications

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