International Conference on Mechanical, Industrial and Materials Engineering 2017 (ICMIME2017)
28-30 December, 2017, RUET, Rajshahi, Bangladesh.

Paper ID: AM-95

Assessment of Surface Roughness Using LVDT: A Convenient and Inexpensive Way of Measuring Surface Irregularities

Sanjida Nasreen, Md.Rokunuzzaman, Samarjith Biswas
Dept. of Mechanical Engineering, Rajshahi University of Engineering and Technology
E-mail:sanjida42nasreen@gmail.com

Abstract

Surface Roughness is a key factor in designing systems as it determines how objects will interact with environment. Surface Roughness measurement can be technically challenging as well as exorbitant. In this paper we develop an efficient and cost-effective approach to surface roughness measurement with Linear Variable Differential Transformer (LVDT). Our approach displays the output using Liquid Character Display (LCD) with standard deviations. The numerical evaluation is based on Center Line Average (CLA) method. We use state-of-the-art microcontroller and other relevant electronics to calibrate the data perceived by sensors. We use output voltage from LVDT as the input to microcontroller to measure vertical displacement and surface roughness. Our proposed approach provides promising and competitive output in terms of accuracy while incurring low costs and execution time. Utilization of LVDT and microcontroller make our proposed approach easily replicable which makes it applicable in industrial production and laboratory.

Keywords: LVDT, CLA, LCD, Arduino, Surface Roughness, Microcontroller.

1. Introduction

In demonstrating the quality of a surface, surface topography assumes an imperative part. In quality control of machining workpiece, manufacturing industry, it should be within certain limit [1]. Surface roughness measuring can be carried out by means of different measurement techniques like Inductance method, Ultrasound & Electronic speckle correlation method [2, 3]. The displacement sensor LVDT can be a convenient device to assist in measuring surface repulsiveness. Advances in microelectronics, manufacturing methodologies and construction materials have significantly improved the performance and cost efficiency of LVDT position sensor [4]. Since its commercial introduction more than 60 years earlier, the LVDT linear position sensor has developed from its underlying use as a laboratory tool to becoming the preferred innovation for critical and reliable linear displacement measurements in industrial, military, aerospace, subsea, downhole drilling, nuclear power and process control application. Now its application extends in many categories. Like, the right stroke for hydraulic applications, position measurement of steam control valves, petroleum extraction, in ATM machines measuring money is correctly dispensed, in flight control systems for military and commercial aircraft etc. In this venture microcontroller based hardware with LVDT sensor is designed and arranged to check the surface roughness in modern production lines and research centre. LVDT is a high exactness position indicator which can quantify the asperity of surface accurately and the roughness of surface is measured by a microcontroller to demonstrate the outcome carefully [8]. So, it can be an initiative to use in the laboratory to measure the surface roughness as well as in production zone of various industries. Its application may extend in many categories by applying different program in the microcontroller. It is pollution free and power consumption is low.

2. System Overview

The wooden frame supporting the LVDT system and other electronics used in the experiment are shown in Figure 1 & 2. Figure 3 illustrates the system overview. The LVDT was kept fixed in the frame and a rough surface ware allowed to slide under it, which helps to calibrate the LVDT. A step-down transformer was used to convert 220 V to 24V & three windings; iron core was used to generate magnetic flux. For alteration of magnetic flux, change of voltage was noticed with various position change of iron core over the rough surface. When, the flux linkage through an electric conductor changes, a voltage is induced in the conductor. In case of LVDT, an object of ferromagnetic material was moved within the flux path which in effect changes the reluctance of the flux path and brings about the change in flux linkage. Thus, mechanical energy (used in moving the ferromagnetic material) was directly converted into electrical energy. The secondary terminal of the LVDT (connected to the multimeter) showed the voltage output. This voltage output was taken as input by digital pin A0.

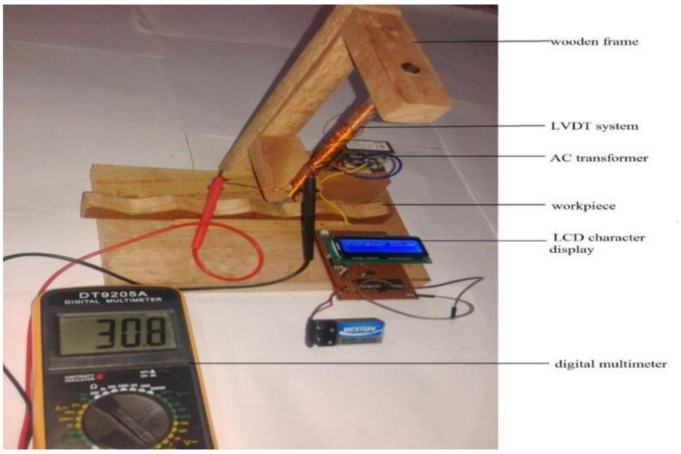
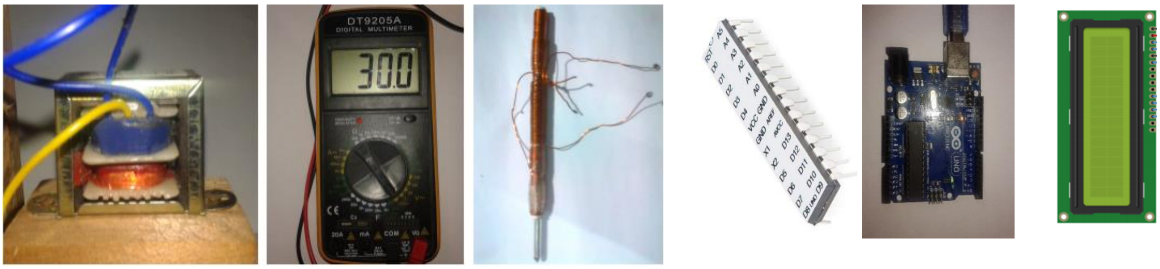


Figure1: Main experimental setup



AC transformer digital Multimeter LVDT ATmega8 Arduino LCD

Figure 2: Various parts of the project

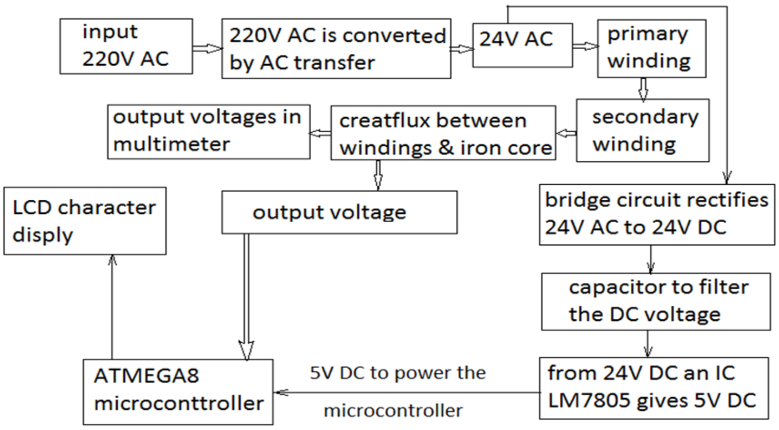


Figure 3: System Overview

2.1 Construction of LVDT

The transformer's internal structure consists of a primary winding centered between a pair of identically wound secondary windings, symmetrically spaced about the primary. The coils are wound on a one-piece hollow spool. This coil assembly is the stationary element of the position sensor. The moving element of an LVDT is a separate tubular armature of magnetically permeable material called the core, which is free to move axially within the coil's hollow bore, and mechanically coupled to the object whose position is being measured. This bore is typically large enough to provide substantial radial clearance between the core and bore, with no physical contact between it and the coil. In operation, the LVDT's primary winding is energized by alternating current of appropriate amplitude and frequency, known as the primary excitation. The LVDT's electrical output signal is the differential AC voltage between the two secondary windings, which varies with the axial position of the core within the LVDT coil. This AC output voltage is converted by an electronic circuitry to high level DC voltage or current. Schematic view of LVDT construction and circuit diagram is given in Figure 4 respectively in (a) & (b).

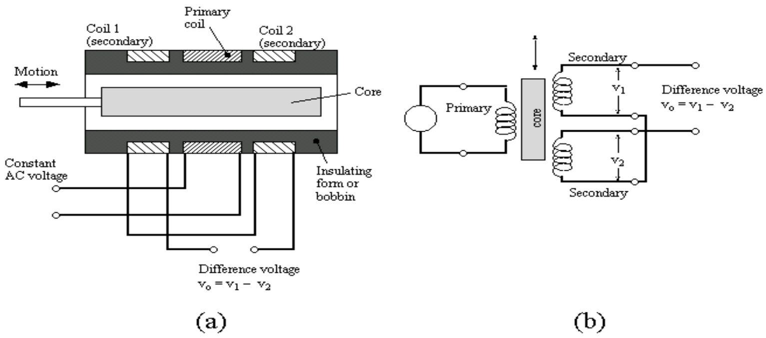


Figure 4: Construction (a) and circuit diagram (b) of LVDT

2.2 Circuit Configuration

To measure and show the result digitally, a microcontroller ATmega8 & LCD digital display is used. In 16*2 LCD display, 6 pin interfaces from 16 pins with the microcontroller. Figure 5 shows the LCD display and its configuration.

The circuit:

- LCD RS pin to digital pin 7
- LCD Enable pin to digital pin 6
- LCD D4 pin to digital pin 5
- LCD D5 pin to digital pin 4
- LCD D6 pin to digital pin 3
- LCD D7 pin to digital pin 2
- LCD R/W pin to ground (digital pin 8)

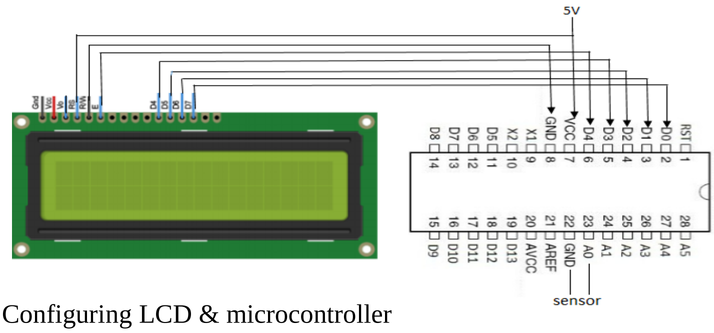


Figure 5: Configuring LCD & microcontroller

To power the microcontroller, 5 V DC supply is needed and the conversion of 24V AC to 5V DC is described in Figure 6. A step-down AC transformer converts 220V AC to 24V AC. A bridge circuit rectifies 24V AC to 24V DC. But, this is pulsating. So, to filter this, a capacitor is used. An IC LM7805 gives constant 5V DC from 24V DC.

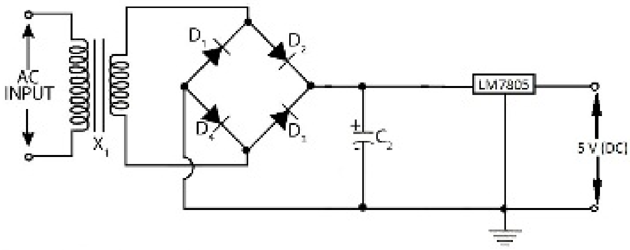


Figure 6: Circuit diagram for 5V DC output

2.3. Communication

In Arduino, the software used on the host computer is known as an integrated development environment, or IDE The development environment is based on the open source processing platform, which is described by its creators as a “programming language and environment for people who want to program images, animation, and interactions [6]. Arduino UNO as shown in Figure 7 was used in this project to compile the program for microcontroller ATmega8 and LCD character display to calibrate & show the displacement and roughness from the output voltage of LVDT.

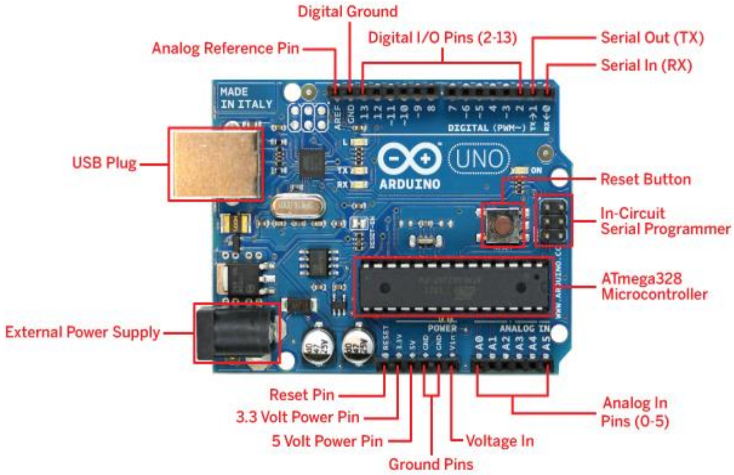


Figure 7: Arduino UNO

The Arduino program contains two main parts: setup () and loop (). The name of the functions implies their purpose and activity: setup () sets up the Arduino hardware, such as specifying which I/O lines is planned to use, and whether they are inputs or outputs. The loop () function is repeated endlessly when the Arduino runs. Arduino IDE (Integrated development environment) is used to write the program and dump into the Arduino board. The program was written and dumped into the Arduino.

3. Calibration of LVDT

When, D is displacement and V is output voltage. Then, the relation is D = VC ………………. (1)
Where, C is the constant or sensitivity of the transformer.
From known surface data the output voltage is found with respect to the horizontal displacement. Here, the output voltages in multimeter and corresponding displacement are,
V =2.9 mV for D = 0.47 cm
So, C = D/V =0.162
V =3.1 mV for D = 0.58 cm
So, C = 0.187
V =2.6 mV for D = 0.35 cm
So, C = 0.132
V =2.5 mV for D = 0.37 cm
So, C = 0.148
Now, C = (0.162+0.187+0.132+0.1480)/4 = 0.157
A sample calculation is given bellow

D= V* Const. D=Displacement of unknown surface
= 7.1 * 0.157 V= Voltage for unknown surface
= 1.1 cm
This calculation is applicable for all experimental calculation. For a sample surface, the voltage Vs displacement curve is drawn.

The graph of Figure 8 shows the output voltage for position of core in different places. The voltage Vs displacement curve shows that the displacement in X axis, and output voltage in Y axis.

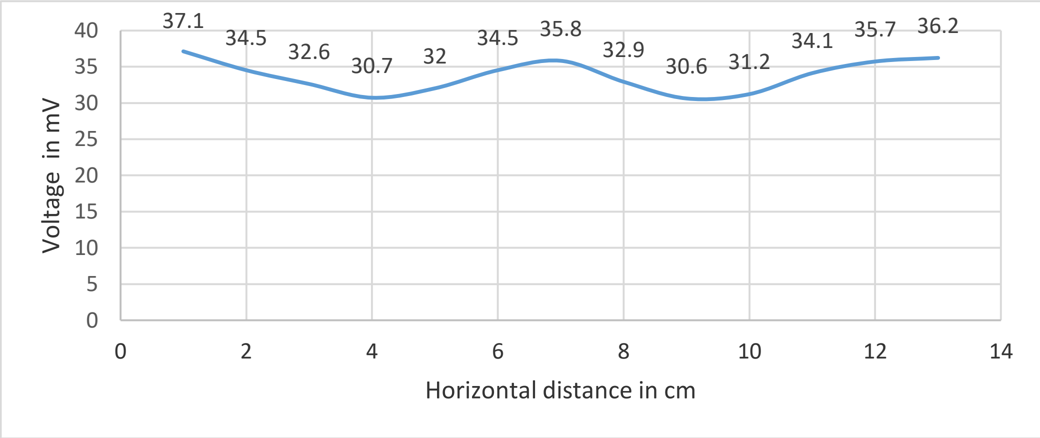


Figure.8: Voltage Vs displacement curve

4. Results

The performance is checked by moving a sample under the LVDT and plotted in a graph. Three other surfaces were also taken to check the performance of the sensor. They are entitled as surface 1, surface 2 & surface 3 are shown in Figure 9.

Surface 1 Surface 2 Surface 3

Figure 9: Three sample surfaces

Sample calculation for performance test of this LVDT:

From the Experimental data table, experimental displacement (D) for the surface with respect to voltages & actual displacement (d) were found. From these values it can be measured easily performance accuracy of LVDT. So a sample calculation is given by bellow which is applicable for all experiments.

Performance of accuracy for the Experiment no.1

$= (100 - \frac{(D-d)}{d} *100)$

$= 100- \frac{0.02}{1.08}*100$

= 98.146 %

Table 1: Table for measuring displacement from output voltage in Multimeter

Horizontal displacement of unknown surface in cm	Output voltage in multimeter in mV	ΔV	Experimental displacement D in cm	Actual displacement d in cm	Percentage of error %	Accuracy
1	37.1	7.1	1.1	1.08	0.0185	98.15
2	34.5	4.5	.71	.85	0.1647	83.53
3	32.6	2.6	.41	.43	0.0465	95.35
4	30.7	.7	.11	.1	0.1	90
5	32	2	.31	.35	0.114	88.6
6	34.5	4.5	.71	.82	0.1341	86.59
7	35.8	5.8	.91	.95	0.0421	95.79
8	32.9	2.9	.455	.5	0.09	91
9	30.6	.6	.09	.08	0.125	87.5
10	31.2	1.2	.2	.2	0	100

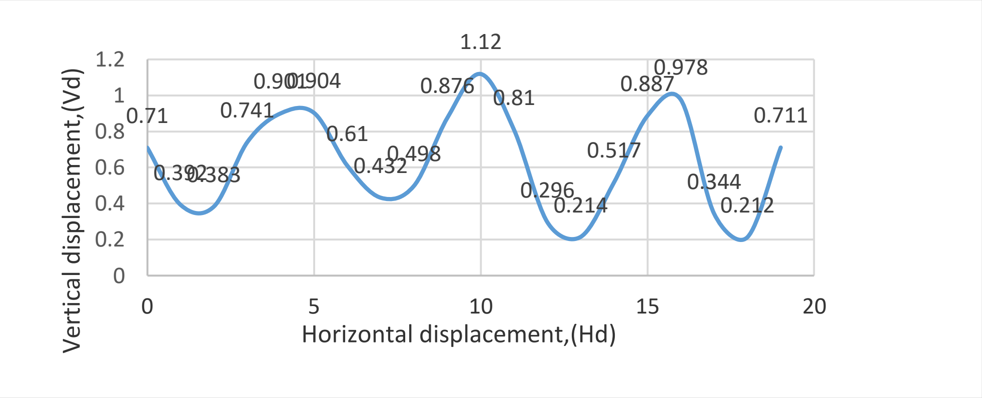


Figure 10: Vd Vs Hd curve by the program

The output values shown in Figure 10 by the display are plotted in graph. The figure shows the vertical displacement against horizontal movement of the surface. 20 data was taken from 19 cm long surface. The deviation per length (cm) was found 0.237.

5. Conclusion

Our proposed approach measures and compares the roughness automatically. Our proposed approach can be used in checking quality of a surface in industry and laboratory. It requires low power to operate and works in clean environment without resulting harmful pollutants. The use of microcontroller makes the system more precise. The construction and operation of the LVDT is simple, cost effective and easily repeatable. Accuracy and efficiency can be further improved by avoiding frictional problem by using a rotating attachment like roller in the tip of the iron core. The diameter of the roller should be smaller for better measurement. The LVDT can be improved by using more windings of carefully chosen diameter. Our proposed approach is applicable to laboratories for academic purpose as well as large scale industrial setups.

References

[1] Yan D., Kaye J. E., Balakrishnan S., Popplewell N.,(1996), "Surface roughness measurements in finish turning". *Journal of Advanced Manufacturing Technology*, Vol. 11, issue 2, page 91-100.

[2] Hitoshi F. & Asakura T., (1997), "Roughness measurement of metal surfaces using laser speckle". *Journal of the optical society of America*, Vol. 67, issue 9, page 1171-1176.

[3] Shin Y. C., Oh S. J., Coker S. A., (2008). "Surface roughness measurement by ultrasonic sensing for in-process monitoring". *J. Manuf. Sci. Eng* vol. 117, issue 3, page 439-447.

[4] Roy A., Rokunuzzaman M., Rabbani G., Roy P. P., (2008). "Construction of low cost Linear Variable Differential Transformer & its calibration". *Journal of Control System and Control Instrumentation*, Vol. 1, issue 1.

[5] Georgios P. P., Pandazaras C. N., J., Davim P (2010). "Multiparameter analysis and modelling of engineering surface texture." *Journal of achievement in materials & Manufacturing Engineering*, vol. 24, issue 1.page 215.

[6] Raghavendra J. S., Venu N. U., Naresh K., (2014), "Linear variable differential transformer using Arduino." A project report in Undergraduate studies, Jawaharlal Nehru Technological University. Hyderabad – 500085

[7] Vemuri A. T., (2014) "Surface Texture Characterization and Evaluation Related to Machining". *Journal of surface integrity in machining*, Vol. 12, page 215.

[8] Metrology for manufacturing surface measurement, R.K. JAIN (2008), Engineering Metrology, 20th Edition, Khanna Publishers Delhi.