International Journal of Scientific & Engineering Research, Volume 7, Issue 12, December-2016
ISSN 2229-5518

Sheet Metal Thickness Measurement Using Capacitive Transducer in LabVIEW

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Abstract— The present work is focused on design and development of a capacitive transducer which is able to measure thickness of a sheet metal at the places where ordinary instrument cannot reach. The instrument converts thickness of sheet metal into change in value of dielectric constant anshows capacitance of the capacitor. Change in capacitance is the measurement of sheet metal thickness. The whole setup is controlled by LabView for accurate and error free measurement. For this purpose, an application programme is designed to produce the output in the required format as a result of repeated observations. The whole setup followed the concept of repeatablity and reproducibility.

Key words —Virtual Instrument, LabVIEW, Capacitive transducer

1 Introduction

Measurement of thickness of sheet metal is a simple and it can be done in so many ways, when somebody wants to do this measurement after using sheet metal into a product then its thickness measurement becomes a very difficult task using non destructive techniques.

This paper presents capacitor sensing device controlled by LabVIEW that controls main system of sheet metal thickness measurement. This consists of two parts; these two parts are coordinated and controlled through LabVIEW software as the main controller of this system. Out of two parts one is capacitive transducer which receives data from sensing device, process information and updates data for the systems, and other one is hardware which transmits signal to LabVIEW [1, 4]. The developed instrument is capable to carry out measurement at the intricate places where other instruments can not work. Block diagram of whole setup is shown in Fig.1

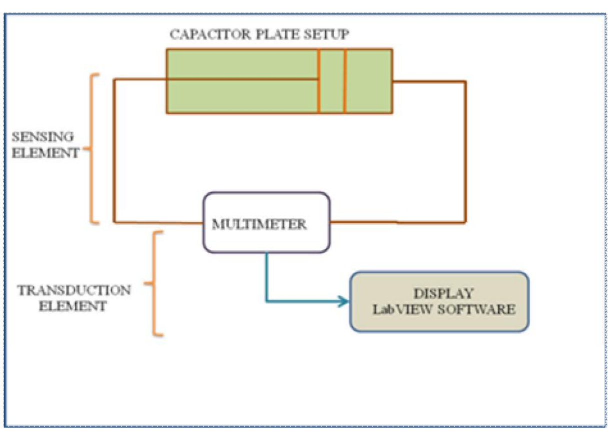

Fig. 1. Block diagram of experimental setup

2. Capacitive Transducer

Sensing element and transduction element are two components for transducer, both being closely related to each other. By changing the physical quantity (pressure, temperature, displacement etc.) measurable response has to be produced by sensor. Sensors output which is mechanical signal would be occurring in transduction element and after conversion into electrical signal output is obtained as a digital form. Arrangement of sensing and transduction elements is shown in Fig. 1.

Extensively capacitive transducer has been used for the measurement of displacement, pressure, force etc. Capacitive transducer or sensor working principle also called as variable capacitance transducer. In capacitive transducer two metal plates are separated by dielectric material such as air. In the typical capacitor the distance between the two plates is fixed, but in variable capacitance transducers the distance between the two plates is variable and kept within a predefined range. In the instruments using capacitance transducer the value of the capacitance changes due to change in the value of the input quantity that is to be measured. This change in capacitance can be measured easily and it is calibrated against the input quantity, thus the value of the input quantity can be measured directly.

In this work initial value of capacitance is measured by inserting a plate of known thickness of same material in between the capacitor plates as dielectric material. Then the sheet metal whose thickness is to be measured is inserted between the plates and change in capacitance is measured as a measurement of the thickness of sheet metal.

3. LabVIEW

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a graphically-based programming language developed by National Instruments. For test measurement, automation, instrument control, data acquisition, and data analysis applications its graphical nature makes it ideal. The LabVIEW software program gives a flexibility to select the steps that the program should do [5]. Part of a software module based on tasking embedded systems, Personal computer LabVIEW interface for monitoring and data processing procedures, data acquisition etc. LabVIEW virtual instrument to instrument control is concentrated in the software module that can be used a variety of ways to display the data collection. LabVIEW is one such software platform where virtual instrumentation can be realized [6].

3.1 Virtual Instruments

Virtual Instrument (VI) is a LabVIEW programming element. A VI consists of a front panel, block diagram, and an icon that represents the program. The front panel is used to display controls and indicators for the user, and the block diagram contains the code for the VI

3.2 LabVIEW Front Panel

Front panel of a LabVIEW VI it contains a knob for selecting the number of measurements per average, a control for selecting the measurement type, a digital indicator to display the output value, and a stop button. An elaborate front panel can be created without much effort to serve as the user interface for an application. Front panel is shown in Fig.2.

3.3 LabVIEW Block Diagram

Block diagram is drawn in LabVIEW as per the standard procedure, The adopted procedure is described below.
The outer rectangular structure represents a While loop, and the inner one is a case structure. The icon in the centre is a VI, or subroutine, that takes the number of measurements per average as input and returns the frequency value as the output. The orange line, or wire, represents the data being passed from the control into the VI. The selection for the measurement type is connected, or wired to the case statement to determine which case is executed. When the stop button is pressed, the While loop stops execution. This example demonstrates the graphical nature of LabVIEW and gives the first look at the front panel, block diagram, and icon that make up a VI. Block diagram is shown in Fig.3.

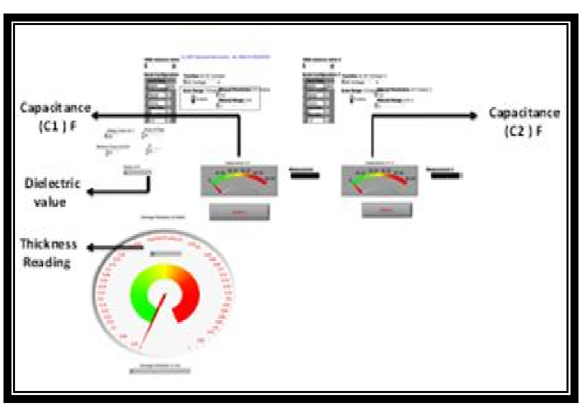

Fig 2. Front Panel

4. Design & Implementation of sensor Control Using LabVIEW

A graphical programme was written in LabVIEW environment whose details are given below.

4.1 Flow of Measurement Signal in LabVIEW

With the help of LabVIEW software, all the calculated values are obtained in the front panel of LabVIEW as output. LabVIEW contains two working panel, front panel and back panel. All the programming has been done in the back panel in the form of graphics. This programming is such that the front panel provides all the required values as the output. Flow of measurement signal is shown in Fig.4.

The results obtained in front panel as output are given below:

- Capacitance of reference plate
- Dielectric constant value of reference plate
- Capacitance of unknown sheet
- Average thickness of unknown sheet

LabVIEW easily connects to any device— hardware or outside applications like Microsoft Excel.

K = Dielectric constant value,C1 = Capacitance of reference sheet (nF),d1 = Thickness of reference sheet metal, A = Area of insulated capacitor plate, C2 = Capacitance value of unknown sheet metal, d = Thickness of unknown sheet

The flow chart of whole programme performed by the LabVIEW software is shown in Fig .4.

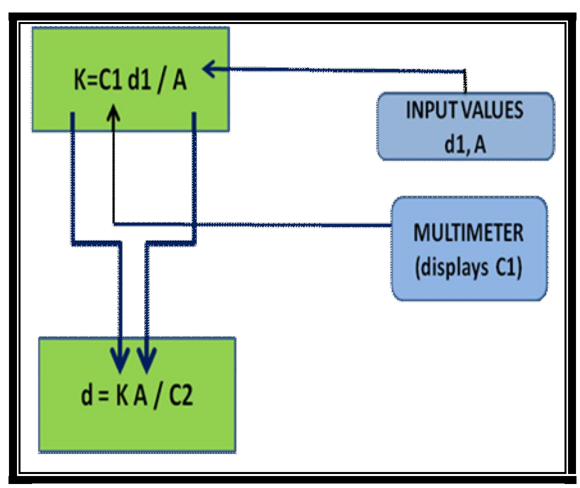

Fig 4. Flow of signal in LabVIEW

5. PLAN OF MEASUREMENT

In the present work, experiment was performed on five samples from six sheets of different thickness for same material. In order to determine the system repeatability and reproducibility, two metal sheets of different thickness are selected randomly for this exercise. For each sheet the value of sample average and sample standard deviation is shown in the Table 1. For complete measurement of unknown thickness, some essential steps which are involved are as follows.

(i) Selection of reference sheet

First measurement is made by taking the reference sheet, for the determination of dielectric constant value. Whenever the reference sheet of known thickness is placed between the parallel plates of the capacitor sensing device, the output is obtained in the form of capacitance value.

(ii) Reading by multimeter

After inserting the reference sheet, multimeter provides the output of sensor in the form of capacitance value. The multimeter is capable to sense the five sample point readings in each operation and deliver the output as average capacitance value.

(iii) LabVIEW software as a transducer output

LabVIEW software receives all the output values (capacitance) given by the multimeter as an input and converts the output values in the form of dielectric constant in this step.

(iv) Measurement of unknown sheet thickens

This is the final step of measurement for unknown thickness. Same material but different in thickness is placed in between capacitor sensing device. Dielectric constant value depends only on the material, hence for same material the value of dielectric constant will be same. The previous data of dielectric constant works as the input value and capacitance of material is measured by sensing device; area of the capacitor sensor plate is same in both the cases. After taking all values itself software (LabVIEW) is capable to display the final thickness of unknown sample.

Table1: Multiple Capacitance value of five samples of different thickness

Capacitance ($10^{-10} \times F$) value for different thickness						
Capacitance	Thickness (.8mm)	Thickness (.76mm)	Thickness (.61mm)	Thickness (.46mm)	Thickness (.3mm)	Thickness (.2mm)
Avg.	1.21	1.31	1.46	1.66	1.88	1.89
STDEV	0.125897	0.215754	0.309677	0.321559	0.235372	0.321248

6. RESULTS AND ANALYSIS

From the analysis of results produced by LabVIEW programming the value of capacitance is found decreasing with the increase in thicknesses and the results justify the capacitance formula as described below.

6.1 Mathematical Relationship

According to capacitance formula relation between capacitance (C), dielectric constant (K), area of capacitor plate (A) and thickness (d) of dielectric material is given by .

$$C = K\ A\ /\ d$$

For same environmental conditions value of dielectric constant K depends only on material for same material value of dielectric constant will be same.

6.2 Value of Capacitance for Different Thickness Sheets

Reading of capacitance in Farad (F) by multimeter for different thickness has been taken to measure five sets of capacitance values in one reading. Variation of sheet thickness with the variation of measured capacitance is shown in Fig.5

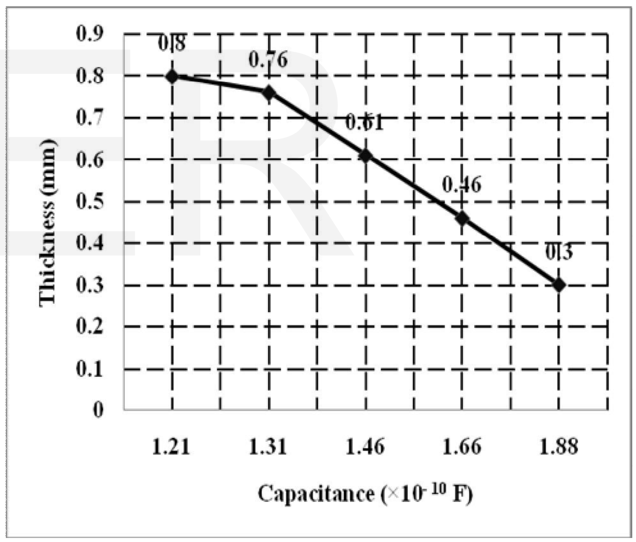

Fig. 5 Thickness vs capacitance

7. CONCLUSION

This fabricated model has been tested successfully and achieved reliable transmission from sensing element to transduction element of whole setup and representation of indications and controls using LabVIEW. The observations are shown in above Table1 and the trend of graph Fig. 5 represents appropriate results.

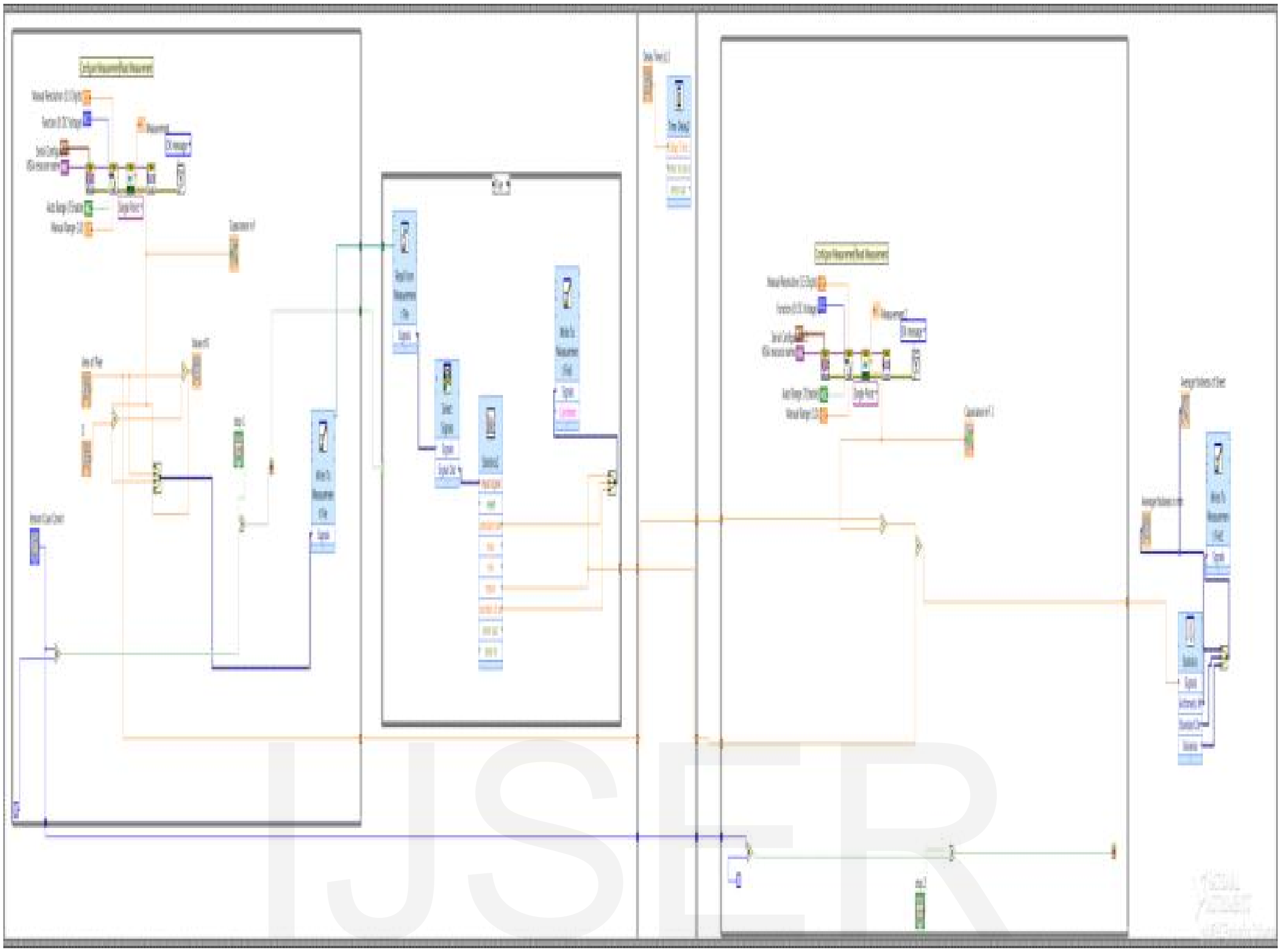

Fig.3 Block Diagram of parameter control VI (Virtual Instrument)

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