QUALITATIVE ANALYSIS OF TWO LIQUIDS IN AN IMMISCIBLE MIXTURE USING ELECTRICAL IMPEDANCE TOMOGRAPHY

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Abstract: This paper describes the design of the Electrical Impedance Tomography system used in specific industrial applications. We make a qualitative analysis of two different liquids in a mixture inside a pipeline with a system of eight electrodes arranged around it. The laboratory set up used by us consists of an array of eight electrodes system in a circular manner with the oil used as the required fluid and water as the mixing fluid. We have carried out the experiment in four steps where the very first step involved having a mixture of oil and water while in the other steps we took a mixture of oil and concentrated water. The voltage density plots for each concentration difference and their respective analysis were performed in a Finite Element Method based Multiphysics Software.

Keywords: Electrical Impedance Tomography (E.I.T.), Finite Element Method (FEM), Sensor system, Concentration, Voltage density plots

I. INTRODUCTION

Electrical Impedance Tomography is a technology, developed in the 70s of the last century and it is based on the concept of image formation. Electrical Impedance Tomography provides information about the conductivity distribution of the inner part of the body forming various images by injecting current into the system having pair of electrodes adhered to the surface. The potential difference obtained is then operated upon by software (e.g. MATLAB, OCTAVE, EIDORS, etc) on a computer to obtain the image. The quality of image enhances with increase in the number of electrodes, the use of too many electrodes may complicate the hardware circuit. EIT is based on the resistivity distribution and impedance of the various tissues of the body. EIT has evolved as a highly efficient methodology for applications like respiratory cycle monitoring and breast scanning. The resistivity of the body may vary with physiological functions and EIT helps in dealing with such variable input variable output system. EIT images can be constructed by using 2D or 3D modes with 3D resulting in high quality image formation.

On account of certain limitations, 2D EIT images are combined to generate one complete 3D image. There are several other imaging techniques like X-ray imaging, CT scan imaging, magnetic resonance imaging, medical ultrasonography, but the non-invasive and portable attributes of EIT make it advantageous over other imaging methodologies. The non-hazardous imaging technique of electrical impedance tomography (EIT) has recently been proposed as a new tool for the supervision of a patient kept under regional lung ventilation in hospitals. Other than medical applications, EIT has been able to diversify itself to various other fields as in geophysical field for the core sample analysis and also in various fields of chemical and fertilizer industries. Since the equipotential surface of EIT has a proportional relationship with the conductivity distribution, there remains always a chance of non-linear construction. The forward problem which involves the finite element method and the inverse problem are the procedures suggested to overcome the non-linear construction method. The finite element method helps in determination of the potential distribution by means of the inner conductivity distribution, while the inverse problem helps in determining the conductivity distribution from the potential distribution. Various such tomography techniques are used in industrial applications for real time process monitoring. It has also been used to determine the mixing time and dispersion velocity in various types of mixture and also in various turbulent flow regions. Typical industrial applications of EIT involve observation of the varying concentration in a mixing process and to obtain control over the process characteristics such as flow rate, temperature control and pressure.

The main objective of this paper is to utilize the principle of Electrical Impedance Tomography to make a qualitative analysis of two different immiscible liquids in a jar, which here is considered analogous to a pipe line in an industry. The jar was surrounded by an array eight electrodes through which the injection of the constant current into the system and the collection of the boundary potentials were carried. The obtained data were analysed in a FEM based two dimensional simulation platform.

II. MATERIALS AND METHODS

2.1. Instrumentation
The hardware architecture of the EIT system involves a current source, digital oscillator circuit, data acquisition system, function generator, multiplexer units and collection of electrodes. The software component consists of an algorithm for image formation and its respective analysis. This working of this system requires a thorough knowledge of instrumentation and other electronic instruments as described in the below sections.

2.1.1 Current Source
The constant current source used here is a modified Howland current source. The current source is capable of delivering a constant current \(\sim 1\) mA for frequency upto \(10\) MHz. High stability and very high output impedance makes it a better choice for its application in E.I.T. field.

The modified Howland current source requires two op-amps specified as AD-8041 and resistances of 1K-ohm with a voltage supply of +5 V and -5V. The circuit diagram of the modified Howland current source is given in Fig. 1.

![Fig 1. A Modified Howland Current Source Circuit Diagram](image)

2.1.2 Multiplexers
Here 8 pin DIP switch were used as the multiplexers for injecting the current into the phantom boundary under consideration and for collection of the boundary potentials from the electrodes.

2.1.3 Data acquisition system.
The potential difference as obtained from the consecutive electrodes is amplified and then transmitted to arduino uno board (ATmega 328) through which a USB serial communication with the computer is made. The data obtained from the system is stored for future analysis. The block diagram of a data acquisition system is shown below:

![Fig 2: Schematic diagram of the developed EIT system.](image)

III. EXPERIMENTAL DETAILS

3.1. Data collection and image construction.
At the beginning the jar is filled with two different immiscible liquids i.e. oil and water. Here, the oil is considered as the wanted liquid while the water is as the unwanted. Data is collected by applying a constant current of 1mA across a pair of electrodes and the boundary potentials between each pair of electrodes are collected using the neighbouring protocol of E.I.T. The obtained boundary potential is then fed to the computer for analysis. FEM based software helps in obtaining the required image which helps in determining the two separate concentrations. Similar data is collected by altering the concentration of the water by using sugar as the additive in four steps. The experimental set-up is shown in Fig 3(a,b).

![Figure 3: Photograph of (a) Phantom with the array of 8 electrode and (b) Experimental setup](image)

3.2 Image construction
Image is reconstructed with the obtained data by using FEM based Multiphysics software using the Forward and Inverse Solver Problem of E.I.T.

IV. RESULTS AND DISCUSSION

The potential difference so obtained is then processed by the software to obtain the following images given in Fig. 4.1-4.4. Fig. 4.1 describes the voltage density plot of water with oil in the jar. The plot clearly depicts the variation of the potentials due to the mixing of the two liquids. The voltage inside the considered phantom area varies from 0.0334 V to 0.6329V in Fig. 4.1, 0.0341 V to 0.3789 V in Fig.4.2,
0.0746 V to 0.6469 V in Fig. 4.3 and 0.00801 V to 0.6743 V in Fig. 4.4.

Figure 4.2 represents a change in the voltage density plot compared to Fig. 4.1 due to the increase in the concentration of the water. Similar analyses are also obtained from the other voltage density plots in Fig. 4.3 and Fig. 4.4 due to the increase in the concentration of the water. Thus this plots qualitatively explains the mixing of the two liquids along with the change in the concentration of any one of the liquid.

Figure 4.4: Voltage density distribution plot for 6% concentrated water with oil mixture.

The deep blue colour in the figure obtained above represents the area occupied by the oil while the light blue are represents the area occupied by water. The deep red region represents the electrode without proper contact with the fluids.

CONCLUSIONS

In this paper, we studied the mixing performance of two immiscible liquids along with the varying concentration of one liquid using a 8 electrode EIT system. The voltage density plot as obtained clearly defines the proportions of the respective liquids in the jar. The increase in the concentration in one of the liquids is also clearly visible in the voltage density plots. Thus the developed system can be used for determining purity of a liquid flow in an industry as well to monitor its concentration.

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