# TWO PHASE MEDIUM IDENTIFICATION USING ULTRASONIC TOMOGRAPHY TECHNIQUE



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# Two Phase Medium Identification Using Ultrasonic Tomography Technique



by

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*Dengan nama Allah yang Maha Pengasih lagi Maha Penyayang*

*To my beloved parents,*

*and my family.*

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| Symbols | Definitions |
|---|---|
| ART | –Algebraic Reconstruction |
| $A_v$ | –Closed Loop Gain of the Inverting Amplifier |
| BP | –Back Projection |
| $c$ | –Sound Velocity |
| CT | – Computed Tomography |
| $Comp\_Error$ | –Composition Error |
| $d$ | –Distance |
| $D$ | –Transmission Coefficient |
| dB | – Decibel |
| ECT | – Electrical Capacitance Tomography |
| EChT | – Electrical Charge Tomography |
| EIT | – Electrical Impedance Tomography |
| EN | –Enable Channel |
| $Enhance(x, y)$ | – Enhance Image of 64 x 64 Pixels Matrices |
| ERT | –Electrical Resistance Tomography |
| $Gas\_Comp$ | –Gas Composition |
| GUI | – Graphical User Interface |
| $G_{(x,y)}$ | –Gaussian Function |

| | |
|---|---|
| HRA | –Hybrid Reconstruction Algorithm |
| HBRA | – Hybrid-Binary Reconstruction Algorithm |
| Hz | – Hertz |
| $H(X)$ | –Entropy Function |
| kHz | – Kilohertz |
| k-NN | –K-Nearest Neighbor |
| LBP | –Linear Back Projection |
| LDA | –Linear Discriminant Analysis |
| $Liquid\_Comp$ | –Liquid Composition |
| MATLAB | –Matrix Laboratory |
| $Max$ | –Maximum Pixel Value |
| $Min$ | –Minimum Pixel Value |
| $N$ | –Size of Data |
| nF | –Nanofarad |
| NMR | – Nuclear Magnetic Resonance |
| NUFFT | –Non-uniform Fast Fourier Transform |
| $N_{Tx,Rx}(x,y)$ | –Normalized Sensitivity Matrices |
| PC | – Personal Computer |
| $p_e$ | –Incident Wave Sound Pressure |
| $p_d$ | –Transmitted Wave Sound Pressure |
| pF | –Picofarad |
| PNN | – Probabilistic Neural Network |
| $p_r$ | –Reflected Wave Sound Pressure |

| | |
|---|---|
| $R$ | –Reflection Coefficient |
| R | –Resistor |
| $S_{Tx,Rx}$ | –Time Propagation |
| SVM | –Support Vector Machine |
| TOF | – Time of Flag |
| $T_{max(Tx,Rx)}$ | – Calibrated Data of Maximum Medium (Gas) |
| $T_{measure(Tx,Rx)}$ | –Measured Data |
| $T_{\min\ (Tx,Rx)}$ | – Calibrated Data of Minimum Medium (Oil or Water) |
| $T_{LBP}(x, y)$ | –Concentration Profiles |
| V | – Voltage |
| $V_+$ | –Input Voltage |
| $V_-$ | –Inverting Voltage |
| $V_{ref}$ | –Voltage Reference |
| Vrms | –Voltage Root Mean Square |
| $V_{s+}$ | –Positive Supply |
| $V_{s-}$ | –Negative Supply |
| $V_{out}$ | –Voltage Output |
| WCT | – Wavelet Co-occurrence Texture features |
| WST | –Wavelet Statistical Texture features |
| $x$ | –Distance from the origin in the horizontal axis |
| $\bar{x}$ | –Mean |
| $y$ | –Distance from the origin in the vertical axis |

| | |
|---|---|
| $Z$ | –Acoustic Impedance |
| $\rho$ | –Density |
| $\sigma$ | –Standard Deviation of Gaussian Distribution (Sigma) |
| $\sigma^2$ | –Standard Deviation |
| μs | –Microsecond |
| 2D | –Two Dimensional |
| 3D | – Three Dimensional |

**MENGENALPASTI PERANTARAAN DUA FASA MENGGUNAKAN TEKNIK ULTRASONIK TOMOGRAFI**

## ABSTRAK

Penggunaan teknik tomografik telah digunakan secara meluas dalam saluran paip dan industri minyak. Teknik ini berpotensi untuk mendapatkan gambaran aliran dan pengukuran dalam pengeluaran telaga. Salah satu proses penting adalah dalam pencirian pelbagai fasa; yang digunakan dalam pemantauan, pengukuran atau mengawal proses industri. Pelbagai fasa mewakili keadaan lebih dari satu fasa.Keadaan dua fasa dikenalpasti dalam kajian ini. Penyelidikan tentang proses tomografi dalam industri terdiri daripada mendapatkan imej anggaran keratan rentas paip atau balang yang mengandungi atau membawa bahan proses. Teknik tomografi ultrasonik adalah salah satu kategori dalam proses tomografi. Sistem tomografi yang mudah boleh dibina dengan memasang beberapa pengesan di keliling paip yang mengufuk. Dalam kajian ini, sebanyak 16 pasangan pengesan ultrasonik 40 kHz yang dipasang bukan secara invasif di sekitar paip. Ciri-ciri pemilihan pengesan yang sesuai perlu dipertimbangkan. Minyak gris digunakan sebagai bahan gandingan untuk memasang pengesan ultrasonik ini. Data keluaran daripada pengesan diperoleh dan diproses untuk mendapatkan maklumat taburan ruang cecair dan udara dalam ruang eksperimen. Kaedah 'Time of Flag' (TOF) telah dipilih untuk mendapatkan data daripada isyarat ultrasonik. Analisis pada isyarat transduser 'telah dijalankan untuk membezakan masa pemerhatian antara gelombang 'longitunal' (lurus) dan gelombang 'Lamb'. Maklumat yang diperolehi dari masa pemerhatian adalah berguna untuk pembentukkan imej-imej. Algoritma 'Linear Back Projection' (LBP) telah digunakan untuk mendapatkan profil tumpuan atau juga dikenali sebagai 'tomogram'. Keputusan yang diperolehi melalui LBP ditapis menggunakan penapis 'Gaussian' dan teknik penapis 'Enhancement'. Daripada imej-imej yang ditapis, pembangunan selanjutnya telah dibuat oleh mengekstrak ciri maklumat itu seperti 'mean', 'standard deviation', 'skewness', 'kurtosis', 'energy', dan 'entropy'. Dua pendekatan telah digunakan untuk tujuan pengelasan iaitu ciri-ciri tunggal dan kombinasi. Perbandingan di antara Pengelas 'K-Nearest Neighborhood' (k-NN) dan Linear Discriminant Analysis (LDA) telah dibuat. Daripada pemerhatian, pengelas bukan linear (k-NN) menghasilkan hasil yang lebih baik berbanding pengelas linear (LDA). Selain itu, didapati bahawa klasifikasi ciri kombinasi memberikan prestasi yang lebih baik daripada pengelasan ciri tunggal.

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## ABSTRACT

The use of tomographic techniques has been widely used in pipeline and oil industry. These techniques have potential applications for flow visualization and measurement in producing wells. One of the important processes is in multiphase characterization; that serve in monitoring, measuring or controlling industrial processes. Multiphase represents the condition of more than one medium phase. The identification for two phase medium is carried out in this research. Research on industrial tomography process revolved in obtaining estimated images in cross section of a pipe or vessel containing or carrying the substances in the process. Ultrasonic tomography technique is one of the categories in process tomography. A simple tomography system can be built by mounting a number of sensors around the circumference of a horizontal pipe. In this research, sixteen pairs of 40 kHz ultrasonic sensor have been non-invasively mounted around the pipe. The characteristic of the sensor is an important factor that needs to be considered. Grease was used as the coupling material to mount these ultrasonic sensors. The output data from the sensors were processed to obtain the information of the spatial distributions of liquid and gas in an experimental column. Time of Flag (TOF) method has been chosen to extract the data from the ultrasonic signals. Analysis on the transducers' signals has been carried out to distinguish the observation time between the longitunal (straight) propagation waves and the Lamb waves. The information obtained from the observation time is useful for further development of the images. The Linear Back Projection (LBP) algorithm has been applied to obtain concentration profiles or also called tomograms. The results obtained through LBP were filtered using Gaussian Filter and Enhancement Filter Technique. From the filtered images, further development was made by extracting features information such as mean, standard deviation, skewness, kurtosis, energy and entropy. Two approaches were applied for classification purposes using single and combination of features. Comparison between K-Nearest Neighbor (k-NN) and Linear Discriminant Analysis (LDA) classifiers have been made. From the observation, non-linear classifier (k-NN) produced a better result over linear classifier (LDA). Furthermore, it has been found that combination of features gives better performance over single feature classification.