TRANSIENT ANALYSIS FOR LEAK SIGNATURE IDENTIFICATION BASED ON HILBERT HUANG TRANSFORM AND INTEGRATED KURTOSIS ALGORITHM FOR Z-NOTCH FILTER TECHNIQUE

MUHAMMAD HANAFI BIN YUSOP

Master of Science

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science in Mechanical Engineering

____

(Supervisor's Signature)

Full Name : IR DR MOHD FAIRUSHAM BIN GHAZALI

Position : DEPUTY DEAN (RESEARCH & POSTGRADE STUDIES)

Date :

____

(Co-supervisor's Signature)

Full Name : MR MOHD FADHLAN BIN MOHD YUSOF

Position : LECTURER

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at University Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : MUHAMMAD HANAFI BIN YUSOP

ID Number : MMM 16001

Date :

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AUTHOR

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LIST OF SYMBOLS

σ	Variance
$Z\infty$	Ikaz Coeffcient
s	Standard Deviation
$\overline{x}$	Mean
x_i	The value of data point
K	Kurtosis
rms	Root Mean Square
f_{max}	Maximum Frequency Span
LF	Low Frequency
HF	High Frequency
VF	Very High Frequency

LIST OF ABBREVIATIONS

NRW	Non-Revenue Water
MDPE	Medium Density Polyethylene
PVC	Polyvinyl Chloride
IWA	International Water Association
AWWA	American Water Works Association
PPA	Pressure Point Analysis
GPR	Ground Penetrating Radar
SNR	Signal to Noise Ratio
FT	Fourier Transform
DWT	Discrete Wavelets Transform
IF	Instantaneous Frequency
HHT	Hilbert Huang Transform
HT	Hilbert Transform
NHT	Normalised Hilbert Transform
HS	Hilbert Spectrum
EMD	Empirical Mode Decomposition
EEMD	Ensemble Empirical Mode Decomposition
GA	Genetic Algorithm
IMF	Intrinsic Mode Function
CWT	Continuous Wavelets Transform
TEO	Teager Energy Operator
DQ	Direct Quadrature
STFT	Short Time Fourier Transform
ECG	Electrocardiogram
MI	Merit Index
MIR	Mutual Information Ratio
Ikaz	Integrated Kurtosis Algorithm for Z-Filter Technique
DAQ	Data Acquisition System
TSA	Time Synchronous Average Algorithm
GUI	Graphical User Interface

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ABSTRAK

Penganalisaan isyarat adalah penting untuk menganalisa data bergerak dan tidak linear. Banyak teknik analisis disediakan untuk memproses data bergerak dan tidak linear seperti FFT, wavelet, dan analisis penyahmodulatan. Dalam satu kajian baru-baru ini, analisis tekanan isyarat fana boleh dilihat sebagai satu kaedah yang tepat dan kos rendah untuk mengesan kebocoran dan pengesanan ciri paip dalam sistem pengagihan air. Fenomena fana berlaku disebabkan oleh perubahan mendadak dalam luang cecair dalam sistem saluran paip yang disebabkan oleh tekanan yang pesat dan turun naik aliran kerana acara seperti penutupan dan pembukaan injap cepat atau melalui kegagalan pam. Pelbagai kaedah analisis fana tekanan telah digunakan oleh beberapa kumpulan penyelidik, seperti analisis cepstrum, cross-korelasi, analisis wavelet, mod empirikal penguraian (EMD) dan analisis kekerapan serta-merta. Dalam kajian ini, adalah dicadangkan untuk menggunakan Hilbert-Huang mengubah (HHT) sebagai kaedah untuk menganalisis isyarat tekanan fana. The HHT adalah satu cara untuk mengurai isyarat ke dalam fungsi mod intrinsik (IMF). Walau bagaimanapun, kaedah ini mempunyai kesukaran untuk memilih sesuai IMF untuk kaedah selepas pemprosesan data seterusnya iaitu Hilbert Transform (HT). Penyelidik terdahulu biasanya memilih IMF visual, berdasarkan pengalaman pengguna, dan memperkenalkan indeks merit yang membolehkan pemilihan automatik daripada IMF. Kertas semasa membentangkan pelaksanaan algoritma berdasarkan kurtosis-bersepadu untuk teknik z-penapis (I-kaz) kepada nisbah kurtosis (I-kaz-kurtosis), untuk ini membolehkan pemilihan automatik daripada IMF yang perlu digunakan. Teknik ini ditunjukkan pada medium paip 57,90 meter polietilena ketumpatan tinggi (MDPE) yang dipasang dengan satu kebocoran untuk demonstrasi replika. Keputusan analisis menggunakan nisbah I-kaz-kurtosis mendedahkan bahawa kaedah yang boleh digunakan sebagai pemilihan automatik daripada IMF, walaupun nisbah tahap bunyi isyarat yang lebih rendah. Walau bagaimanapun, kaedah nisbah I-kaz-kurtosis adalah disyorkan sebagai salah satu cara untuk melaksanakan teknik pemilihan automatik daripada IMF untuk HHT analisis.

ABSTRACT

Signal processing is an important tool to analyse non-stationary and non-linear data. Many techniques of analysis are available to process non-stationary and non-linear data such as FFT, wavelets transform, and demodulation analysis. In a recent study, the analysis of pressure transient signals could be seen as an accurate and low-cost method for leak and feature detection in water distribution systems. Transient phenomena has occur due to the sudden changes in the fluid's propagation in pipelines system caused by the rapid pressure and flow fluctuation. This is due to events such as closing and opening valves rapidly or through pump failure. Various methods of pressure transient analysis have been applied by several groups of researchers, such as cepstrum analysis, cross-correlation, wavelets analysis, empirical mode decomposition (EMD) and instantaneous frequency analysis. In this research, it is to apply the Hilbert-Huang transform (HHT) as a method to analyse the pressure transient signal. The HHT is a way to decompose a signal into intrinsic mode functions (IMF). However, this method has the difficulty in selecting the suitable IMF for the next data post-processing method, which is Hilbert Transform (HT). Previous researchers normally select the IMF visually, based on the user's experience, and introduced a merit index that allows the automatic selection of the IMF. The current research presents the implementation of an integrated kurtosis-based algorithm for a z-filter technique (Ikaz) to kurtosis ratio (Ikaz-kurtosis), for this allows automatic selection of the IMF that should be used. This technique is demonstrated on a 67.90-meter medium high-density polyethylene (MDPE) pipe installed with a single artificial leak demonstrator. The results using the Ikaz-kurtosis ratio revealed that the method could be used as an automatic selection of the IMF even though the noise level ratio of the signal is lower. Despite this, the Ikaz-kurtosis ratio method is recommended as a means to implement an automatic selection technique of the IMF for HHT analysis.

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