Engine Noise Source Identification using Advanced Signal Processing Methods for Noise based Control and Fault Diagnosis

Introduction

The research on engine noise source identification using advanced signal processing methods plays a pivotal role in improving the efficiency, reliability, and environmental impact of internal combustion engines. It addresses challenges related to performance optimization, emissions reduction, diagnostic capabilities, and compliance with regulatory standards. Here, our objective is to decompose engine noise into its constituents, and we have identified that both ICWF and TVF-EMD & RobustICA exhibit superior performance in achieving this goal.

Improved Cyclic Wiener filter

Taking cylinder pressure $P(t)$ as reference signal, the thermal source-induced vibration can be estimated by convolution with improved Cyclic Wiener filter $G(t)$ in the time domain.

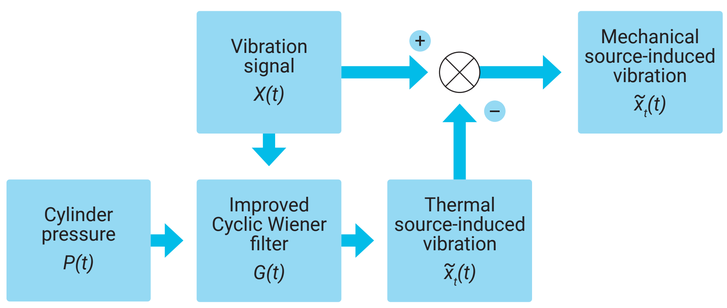


Figure 1. Theory of Improved Cyclic Wiener Filter (ICWF)

ICWF has the capability to extract specific features from the original signal using an Asymmetric Tukey Window (ATW).

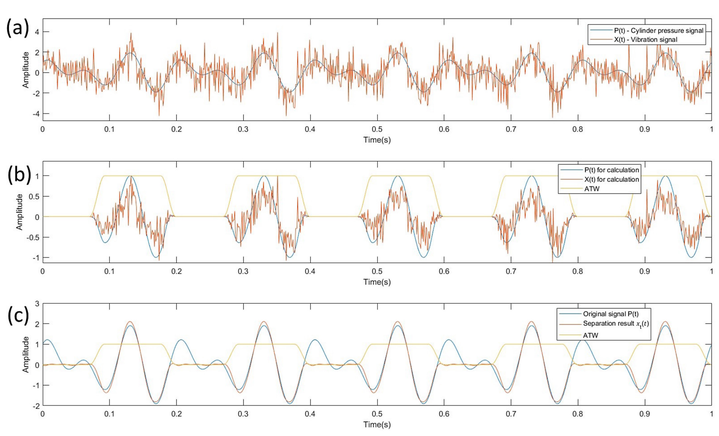


Figure 2. Simulation result with ICWF. (a) Original signal, (b) Signal for calculation with Asymmetric Tukey Window (ATW) and (c) Separation result

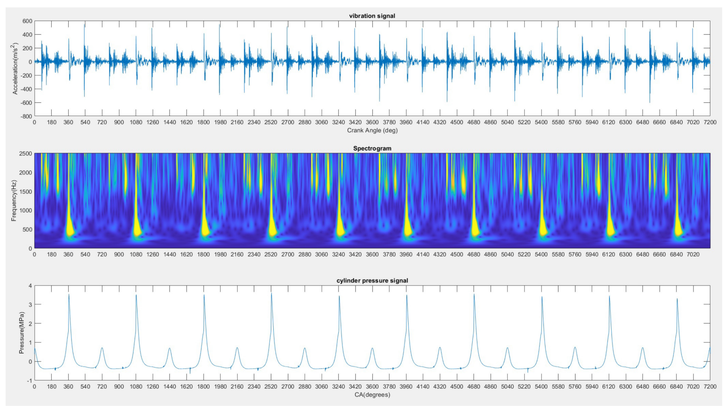


Figure 3. Vibration signal (a), Spectrogram of vibration signal (b) and cylinder pressure signal, (c) obtained by Lublin University of Technology

ICWF effectively identifies combustion-induced vibrations from mechanical vibration data, thereby contributing to engine fault diagnosis and control.

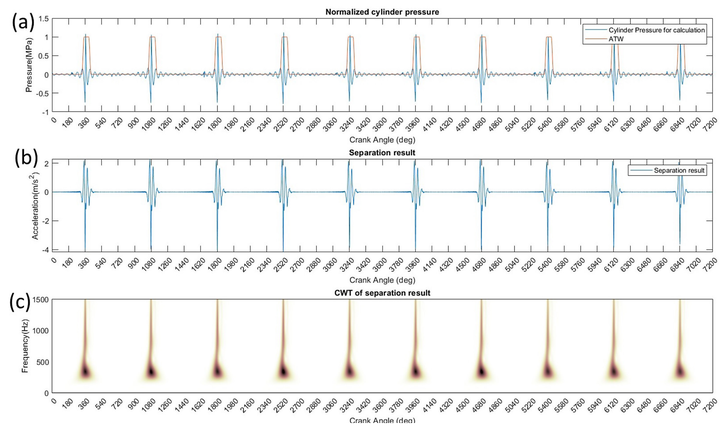


Figure 4. Separation results of real data. (a) Cylinder pressure signal for calculation with ATW, (b) Separation result represents combustion-induced vibration, and (c) Spectrogram of separation result

TVF-EMD & RobustICA

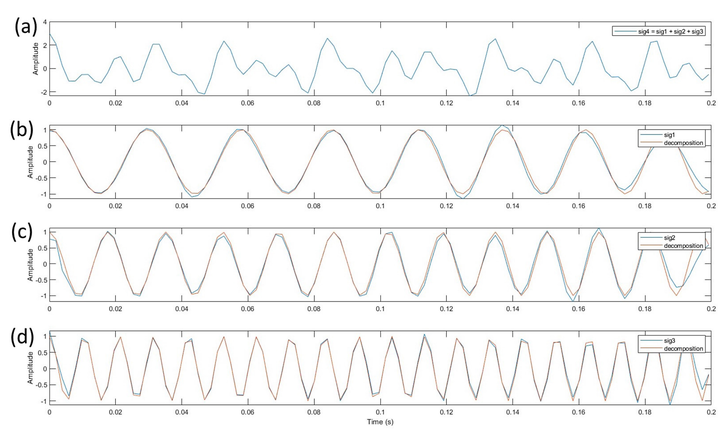
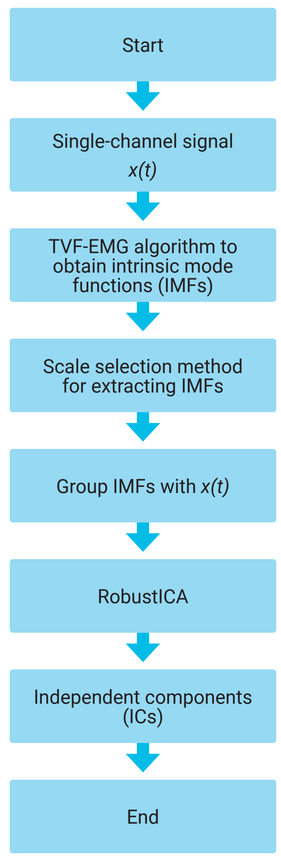


Figure 5. Original signal (a) and comparison of source signals sig1 (b), sig2 (c), and sig3 (d) with their corresponding decomposition results by TVF-EMD & RobustICA

TVF-EMD & RobustICA possesses the capability to identify various source signals by decomposing the original signal into several intrinsic mode functions.

TVF-EMD & RobustICA Algorithm



1. Apply the TVF-EMD method to decompose the single-channel noise signal into multiple IMFs.
2. Utilize the scale selection method to identify and utilize the relevant IMFs for subsequent calculations.
3. Combine the selected IMFs with the original single-channel noise signal as observed signal.
4. Employ the RobustICA method to extract independent components.
5. Identify individual noise sources from the extracted independent components.

Figure 6: Algorithm of Time-Varying Filtering based on Empirical Mode Decomposition with Robust Independent Component (TVF-EMD & RobustICA).

The TVF-EMD & RobustICA method effectively decomposes the mechanical vibration signal into 14 independent components. Subsequent analysis allows for the identification of various excitation sources from these components.

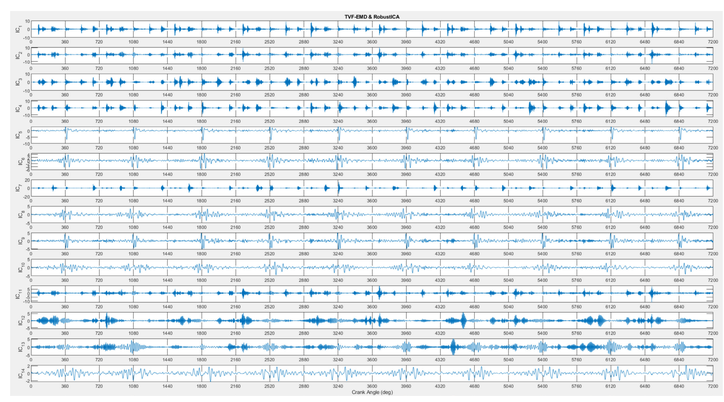


Figure 7. Decomposition results of real data with 14 Independent Components

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