ESTABLISHMENT OF SPECTRAL SUBTRACTION-BASED ALGORITHM FOR EXPERIMENTAL MODAL ANALYSIS UNDER OPERATING CONDITION

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DOCTOR OF PHILOSOPHY

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

We hereby declare that We have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy in Mechanical Engineering.

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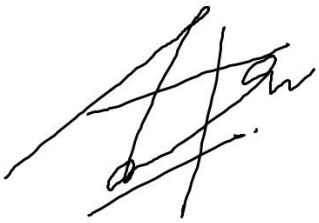

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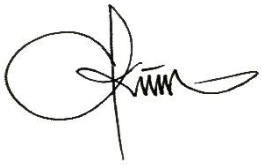

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ABSTRAK

Ujikaji analysis ragaman (EMA) merupakan salah satu teknik yang digunakan dalam mengenalpasti sifat-sifat dinamik sesuatu struktur. Berdasarkan prosedur dalam EMA, pengukuran daya input dan sambutan getaran bagi pengiraan fungsi rangkap pindah perlulah dijalankan ketika sistem berada di dalam keadaan tutup operasi bagi mengelakkan kewujudan daya-daya yang tidak dapat diukur hasil daripada pengoperasian mesin. Dalam keadaan pengoperasian mesin, kehadiran daya-daya yang dihasilkan oleh mesin akan menyebabkan ralat dalam pengiraan fungsi rangkap pindah. Disebabkan itu, sambutan getaran yang diukur memerlukan satu proses penurasan untuk mengurangkan sambutan yang disebabkan oleh daya dari pengoperasian mesin dan dalam masa yang sama hanya mengekalkan sambutan yang terhasil daripada daya impak buatan. Satu algoritma penurasan yang baharu berdasarkan adaptasi penuras penolakan spektrum telah dibangunkan bagi mengekalkan sambutan impak dalam prosedur EMA. Asas dalam penuras ini adalah untuk mengenalpasti magnitud ambien yang terdapat dalam spektrum getaran yang diukur dan menggunakan penuras penolakan spektrum untuk mengurangkan ciri-ciri ambien. Satu parameter yang dikenali sebagai Magnitud Ambien Berkesan diperkenalkan bagi tujuan penambahbaikkan parameter faktor gadaan dalam penuras penolakan spektrum. Parameter ini dikira berdasarkan leraian vektor ambien yang merujuk kepada arah sambutan impak pada setiap jalur frekuensi. Arah bagi sambutan ambien dianggar berdasarkan kepada ambien buatan yang dibina semula. Pembinaan semula ambien buatan dilakukan dengan mengambilkira data pra-terpicu bagi sambutan getaran yang diukur. Dalam prosedur yang dibangunkan, jumlah bilangan data pra-terpicu ditetapkan bersamaan dengan data pasca-terpicu dan data ambien buatan dibina semula dengan menjumlahkan siri Fourier bagi data pra-terpicu. Proses pembinaan semula ambien buatan menghasilkan satu set data yang lebih panjang iaitu bersamaan dua kali ganda panjang asal data pra-terpicu. Data ambien buatan adalah merupakan set data yang diambil daripada separuh kedua data yang dihasilkan. Daripada pemerhatian yang dijalankan menerusi kajian ini, input sambutan yang lebih konsisten boleh menghasilkan ambien buatan dengan aras kesamaan yang lebih baik dengan mengambilkira perbandingan dengan ambien asal. Penemuan ini mempunyai perkaitan dengan kecekapan process penurasan, di mana input ambien buatan yang mempunyai aras kesamaan yang tinggi iatu kurang daripada 5% perbezaan boleh mengurangkan kadar ambien dengan lebih berkesan. Bagi keadaan mesin sedang beroperasi, Fungsi Sambutan Frekuensi (FRF) menunjukkan ciri-ciri berbeza pada frekuensi operasi jika dibandingkan dengan data garis-dasar. Dengan penggunaan penuras yang dihasilkan menerusi modifikasi penuras penolakan spektrum, ciri-ciri asal dalam FRF berjaya dikekalkan sehingga tahap 90% persamman dan pada masa yang sama berupaya menyingkirkan kesan-kesan yang disebabkan oleh daya ambien. Hasil yang diperolehi menunjukkan modifikasi penuras penolakan spektrum yang dibangunkan dalam kajian ini boleh digunakan untuk menghasilkan sambutan impak yang bersih bagi pengukuran yang dijalankan dalam keadaan mesin sedang beroperasi. Kaedah ini dicadangkan untuk diaplikasi dalam prosedur EMA di mana proses penurasan dijalankan sebelum pengiraan FRF bagi meningkatkan keberkesanan prosedur EMA bagi pengukuran dengan kewujudan daya ambien.

ABSTRACT

Experimental modal analysis (EMA) is one of the techniques used to identify the dynamic properties of a structure. In the EMA procedure, the input force and vibration response measurement for transfer function calculation is carried out under shut-down conditions to prevent unmeasurable forces induced by the operating machinery. Under the operating condition, the presence of unmeasurable forces causes an error in the transfer function calculation due to incomplete information of input forces. Therefore, output response from the measurement requires a filtering process to suppress the response from operating forces and retain only the response from the artificially induced force. A new filtering algorithm adopted from a spectral subtraction filter was developed to preserve the impact response in impact-based EMA. The basis of this filter was to identify the amount of ambient magnitude contained in the measured vibration spectrum and utilised the spectral subtraction filter to suppress the ambient features. An effective ambient magnitude parameter was introduced to improvise the gain factor in the spectral subtraction filter. This parameter was calculated based on resolved ambient vector in the direction of impact response at each frequency band. The direction of ambient response at each frequency band was estimated based on the reconstructed artificial ambient. The artificial ambient was reproduced based on pre-triggered data in measured vibration response. In this procedure, the number of pre-triggered data was set as equivalent to the post-triggered data, and the artificial ambient was reconstructed from the summation of Fourier series of the pre-triggered data with twice the original length. The artificial ambient was selected from the second half of the reconstructed signal. From the research observation, a higher consistency level with approximately less than 5% deviation for the input ambient response produce higher similarity in artificial ambient with respect to actual ambient. This finding correlated with the efficiency of the filtering process, whereby the input with a higher similarity artificial response suppresses a more accurate amount of ambient and retains more than 90% of the baseline features. Under the operating condition, the measured frequency response function (FRF) showed non-identical features at operating frequencies as compared to the baseline data. The utilisation of the filtering process based on the modified spectral subtraction filter had successfully restored the essential features in FRF and suppressed unwanted ambient consequences. The findings indicated that the modified spectrum subtraction filter could be utilised to extract the clean impact response under consistent operating conditions. It was suggested this method be applied prior to FRF calculation to enhance the EMA procedure under ambient operating forces.

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