# Structural Health Monitoring of Offshore Platforms in the Persian Gulf Using "SIJacket©" Computer Program For Ambient Vibration Tests

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*Damage detection, system identification, SIJacket©, offshore structure, steel jacket, spectral analysis, ambient vibration, nonstationary, nonlinear.*

## 1. Introduction:
Three existing platforms in the Persian Gulf were selected and their ambient vibrations were recorded in several intervals. The platforms had been installed in a deep sector of Persian Gulf, with 67 meters water depth. The production platform was four legged steel jacket structure with six horizontal bracings in height and grouted piles. Penetration of piles, were equal to 60 meters. The Jacket had a boat-landing, two oil risers which were connected to legs by clamps and a $H_2S$ riser from –24 meter to cellar deck. The platforms had a service life of 30 years at the time of vibration recordings (Fig. 1).

*Fig. 1-An overview of platforms*

A procedure was developed to implement the Welch method for estimating the Power Spectral Density function (PSD), by using the nonstationary algorithms. The emphasis was to illustrate the nonstationary signal processing for offshore structures and to implement a new method for higher resolution of PSD. The Partial Stationary concept (developed by Aghakouchak and Ghafooripour) was described for the nonstationary records, which contain neither quasi-stationary nor locally stationary specifications. The Wigner-Ville distribution was used for non-stationary analysis relevant to Partial Stationary concept. Also, confidence interval for checking the threshold of nonstationarity was used in this new method. Therefore interpretation of results for health monitoring of a jacket will be possible with sensitive feature.

A method for using the Bessel-Kaiser window shape function to estimate damping value from the Power Spectral Density function (PSD) was applied for gathered data. The Bessel-Kaiser window is an approximation to the prolate window and is more efficient compare to the other window shape functions. In this method ratio of the main lobe energy to the side lobe energy of spectrum is maximized.

## 2. Developing SIJacket© Program:

During data processing steps, different computer programs were evaluated and finally Matlab® program was chosen as basic program. Some advantages of the Matlab® program are: powerful calculation platform, rich library of mathematical functions, ability of customizing and writing new functions and toolboxes, and also wide usage in research and technical papers in this field.

There are many standard and customized toolboxes in Matlab®, but for system identification and health monitoring, preparation of a new program was yet required. Hence SIJacket© program was written by authors based on the new concepts and methods in this field as described above. Main features of SIJacket© program are:

- ✓ Developing all new described concepts and methods in one program.
- ✓ User-friendly GUI (Graphical User Interface).
- ✓ Processing and plotting recorded vibrations of structures (Fig. 2).
- ✓ Calculation of probability distribution function (Fig. 3).
- ✓ Using the spectral system identification for ambient vibration tests (Frequency and time-frequency methods).
- ✓ Frequency and damping identification, with observing error origins in damping and frequency identification for ambient method (Fig. 4).
- ✓ Developing a method for using the Bessel-Kaiser window shape function to estimate damping value.
- ✓ Possibility of using standard window shape functions.
- ✓ Estimation of statistical random and bias errors and suggestion of the allowable errors for given data is possible.
- ✓ Selection of the required window length, sampling duration of records, number of data in each time series, number of averages and interval time.
- ✓ Optimum design and calculation of adjustable value (β) for Bessel-Kaiser window function based on the specification of time series and offshore dynamic characteristics.
- ✓ Calculating statistical confidence and errors for checking the nonstationary behavior of records by the new Partial stationary concept.
- ✓ Calculating Power Spectral Density function (PSD) based on minimum bias errors via Bessel-Kaiser function and optimum random error.
- ✓ Baseline correction ability (for time series).
- ✓ Plotting FFT, phase angle and coherency diagrams (Fig. 5).
- ✓ Applying data resampling and FIR filters are possible.
- ✓ Possibility of defining desired peak values of PSD or Periodograms and saving in a file.
- ✓ Plotting and defining desired values in "Waterfall" display of records during the time to study about nonstationarity of records and therefore nonlinear behavior of offshore structures could be detected (Fig. 6).
- ✓ Calculating and plotting "Wigner-Ville" distribution for computing variations of frequencies over the time. This will compare the effects of appendage frequencies, which cause multiple peaks in PSD and variation of frequencies, with nonlinear behavior of offshore (Fig. 7).

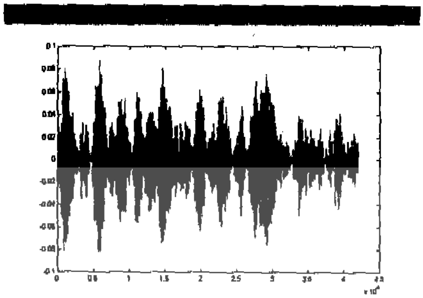

Fig. 2- Sample records from offshore structure

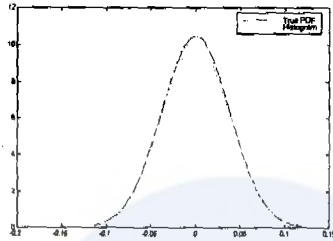

Fig. 3- Probability distribution function

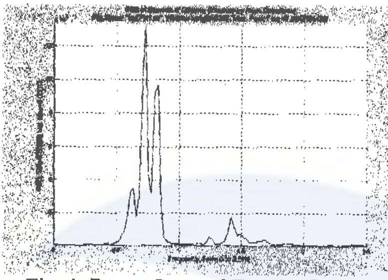

Fig. 4- Power Spectral Density function

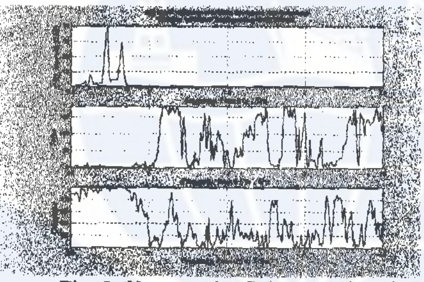

Fig. 5- Phase angle, Coherency function

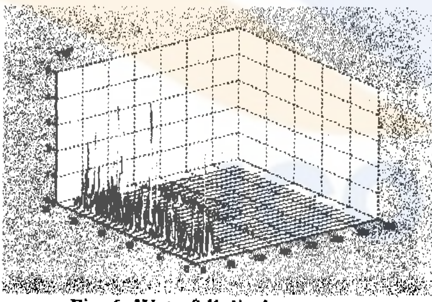

Fig. 6- Waterfall display

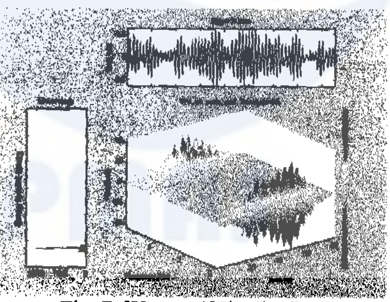

Fig. 7- Wigner-Ville distribution

Note that this program originally has been prepared as a ready to use program for spectral system identification of jacket type offshore structures for recorded data from ambient vibrations. But it may also be used with some small changes, for similar applications.

## 3. Conclusion:

This paper discusses and presents the system identification and health monitoring method for offshore structures. The proposed methods are implemented in SIJacket© computer program which may be used for steel jacket type platforms in Persian Gulf.

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