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APPLICATION OF FOURIER SERIES IN MICROTREMOR ANALYSIS, CASE STUDY ON DISASTER RISK MANAGEMENT WORTH MINING REGION IN BLITAR DISTRICTS, EAST JAVA

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Abstract

Mining activities can alter Earth's surface layer that has a high impact on disaster risk. Disaster risk in the mine area can be determined by using the method of calculation Amplification Factor (AF) based on interpretation of microtremor analysis Kanai and Nakamura. Fourier Spectrum analysis is used to obtain a frequency distribution curve of the magnitude to obtain the dominant frequency and dominant period. Tremor data processing using Fast Fourier Transform (FFT), the process of transformation of form time domain to the frequency domain in order to obtain the Fourier spectrum of each component. This spectrum can be determined from the analysis of spectral ratio (SR) which is the amplification factor (AF) based on interpretation Nakamura, and the predominant period (T dom) based interpretation Kanai. Based on the results obtained amplification factor, can be obtained by interpretation of the existence of the condition of the surface layer of soil instability

Keywords: Fourier series; Fourier spectrum; analysis of microtremor

INTRODUCTION

Indonesia has a wealth of natural assets is so great to be managed and utilized, either from its own local government and local communities, especially in the mining sector. However, mining activities can change the state of the surface layer of the earth that have a high impact disaster risk. This could threaten the safety and disrupt human life, also environmental damage. Mining activities also resulted in changes in the movement of the earth's surface layer is not stable.

If this is allowed, then it lead to a high risk of disaster, seen from the surface layer of the earth between the insistence that move gradually each other, then followed by a process of erosion of rocks, ranging from rough to smooth known as tailings. The impact of the tailings surface layer causing avalanches and experienced shallowness, so that the environment surrounding ecosystem could be disrupted.

For it is necessary to manage and reduce disaster risk in the mining region, using the calculation method Amplification Factor (AF) of mikrotremor analysis. .Fourier series and Fourier spectrum instrumental in establishing and analysis to obtain a frequency distribution curve of the magnitude to obtain the dominant frequency and dominant period. Tremor data processing using Fast Fourier Transform (FFT), the process of transformation of form time domain to the frequency domain in order to obtain the Fourier spectrum of each component. This spectrum can be determined from the analysis of spectral ratio (SR) which is the amplification factor (AF). These results will be used as the initial interpretation to determine which areas are prone to disasters and that is not at the mine site, dan and as a information tool to support community development in terms of settlement, social environment, and the landscapes.

EXPLANATION

Microtremor or referred to as ambient noise works at low amplitude produced by subsurface movement caused by : artificial disturbances such as traffic, factory machinery, and other human activities on the earth's surface. Or it can also be caused by natural sources such as wind and ocean waves.

Natural wave of mikrotremor vary, depending on the conditions of different regions. The basic principle of the application of microtremor is the study of subsurface effects, namely: microtremor move as waves below the surface and amplified in the period made in sync with the natural period in the sub-soil, along with the selection of the resonance, and increased frequency component. At the time period microtremor tend to reflect the subsurface formation, the period length is always associated with the formation depth. Microtremor observation survey conducted to determine the dynamic characteristics of the surface layer, such as resonant frequency and seismic vulnerability index (Nakamura, 2000).

There is a correlation between the characteristics of the spectrum of microtremor with the level of damage caused by the earthquake which shows that microtremor spectral peaks rise on sedimentary formations in with the fine sediment material.

The intensity of damage and the amplification factor of high seismicity in the earthquake, usually occurs in a location with the pattern of microtremor spectrum at the low resonance frequency (fdom) with high spectral peaks (dominant period (Tdom)). Conversely, the intensity of damage and low seismic amplification factor occurs in a location with the pattern of microtremor spectrum at the high resonance frequency (fdom) with low spectral peaks (dominant period (Tdom)).

A. Types of waves associated with the Microtremor Analysis

Characteristics of waves that propagate through the rock layers of the earth's crust can be distinguished as follows:

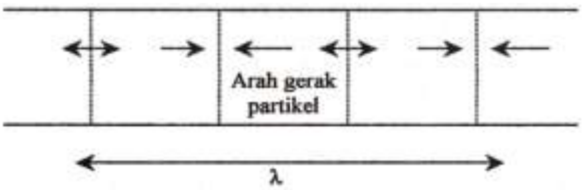
1. Body Waves

   Body wave is a wave that propagates in the layer of the earth.

   In general, this wave consists of:

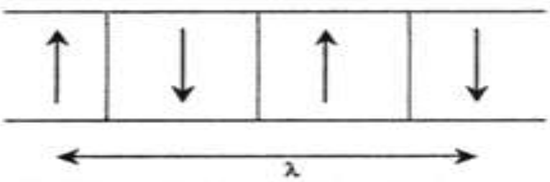
a. Primary wave

   These waves are also called longitudinal waves. Primary wave induced motion of medium particles in the direction parallel with the direction of wave propagation. At this wave seismograph recordings always came first. Primary waves can propagate in solid or liquid media.



b. Secondary / Shear Wave

   These waves are also called transverse waves. These waves cause movement of medium particles in the tangential direction to the direction of wave propagation. At this wave seismograph recordings arrive after primary waves.



2. Surface waves

   Surface waves is a complex wave with the low frequency and large amplitude, which propagates in a wave of semi-infinite elastic medium surface. Wave velocity values between 500-600 m / s. Properties and particle motion media on the surface there are similar to the P wave or S wave. Basically there are two types of surface waves based on the elastic properties of the medium particle motion, namely:

a. Rayleigh Wave

   Rayleigh waves are surface waves that move the medium particles is a combination of media particle movement caused by the P wave or S wave. Orbit movement of particles is elliptical movement with the ellipse major axis perpendicular to the surface and the direction of propagation. These waves propagate along the surface of the solid.

b. Love Wave

   Love wave is a surface wave that propagates in the form of transverse waves. Particle movement due to wave propagation equal or similar to an S wave. This wave has no component upright. These waves propagate along the boundary of two media.

B. Mathematical formulation related to Microtremor Analysis

In many applications in mathematical techniques, often found that periodic functions, and the problem that arises is to present the general periodic functions. Joseph Fourier developed a cohesive theory of this kind of series (Robert Wrede, Murray, 2002). One approach used to present these functions is to use the method of Fourier series (Prayudi, 2006)

1. Fourier Spectrum Analysis

An analysis to obtain the frequency distribution curve magnitude, so that the frequency of dominant and dominant period.

Calculation predominant period of vibration micro performed using Fourier spectrum analysis as follows:

Suppose a uniform homogeneous Fourier series of periodic functions to f (t) with period T in (-T / 2, T / 2) so that :

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\sim}(a_n Cos\ w_n t + \ b_n \sin\ w_n t) \quad \text{.........................(b.1)}$$

Wich is

$$\left.\begin{aligned} a_n &= \frac{2}{T}\int_{-T/2}^{T/2} f(t) Cos\ w_n t\ dt \\ b_n &= \frac{2}{T}\int_{-T/2}^{T/2} f(t) Sin\ w_n t\ dt \end{aligned}\right\} \quad \text{..................................(b.2)}$$

Complex form of the Fourier series can be determined by using the Euler formula $E^{i\emptyset} = Cos\ \emptyset + I\ Sin\ \emptyset$, it is obtained :

$$\left.\begin{aligned} Cos\ w_n t &= \frac{e^{iwnt} + e^{-iwnt}}{2} \\ Sin\ w_n t &= \frac{e^{iwnt} + e^{-iwnt}}{2} \end{aligned}\right\} \quad \text{......................................(b.3)}$$

Equation (b.3) is disubstitusikan to equation (b.1) and (b.2), then obtained :

$$f(t) = \sum_{n=-\sim}^{\sim}\left(\frac{a_n - ib_n}{2}\right) c^{iwnt}$$

$$= \sum_{n=-\sim}^{\sim}\left(\frac{2\pi}{T}\right) f(iw_n).\ c^{iwnt} \quad \text{......................................(b.4)}$$

then obtained :

$$F(iw_n t) = \frac{1}{2\pi}\int_{-T/2}^{T/2} f(t) c^{-iwnt} dt \quad \text{..................................(b.5)}$$

Fourier spectrum is defined as :

$$SF = 2\pi\,|F(Iw_n)|$$
$$= \left|\int_{-T/2}^{T/2} f(t)e^{-iwnt}dt\right|$$
$$= \sqrt{(\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t).Cos\, w_n t\, dt)^2 + (\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t).Sin\, w_n t\, dt)^2}$$
$$= \sqrt{(\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t).Cos\, w_n t\, dt)^2 + (\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t).Sin\, w_n t\, dt)^2}$$
$$= T/2\sqrt{a_n{}^2 + b_n{}^2} \quad \text{..........(b.6)}$$

To see the curve of the Fourier spectrum for the periodic function f (t) having no finite period T can be derived as follows:

To reach out to non-finite T, then equation (B.6) becomes:

$$f(t) = \int_{-\sim}^{\sim} A(w)Cos\, wt\, dw + \int_{-\sim}^{\sim} B(w)Sin\, wt\, dw \quad \text{..........(b.7)}$$

Wich is

$$\left.\begin{aligned} A(w) &= \int_{-\sim}^{\sim} \frac{1}{\pi} f(t)Cos\, wt\, dt \\ A(w) &= \int_{-\sim}^{\sim} \frac{1}{\pi} f(t)Cos\, wt\, dt \end{aligned}\right\} \quad \text{..........(b.8)}$$

Fourier integral formula is not valid if f (t) are eligible :

$$\int_{-\sim}^{\sim} |f(t)|dt < \sim \quad \text{..........(b.9)}$$

In the implementation of functionality that meets the above conditions is a function that decays to zero when | (t) | approaches infinity. While equation (b.5) becomes :

$$f(t) = \lim_{\Delta w \to 0} \sum f(t)$$
$$= \lim_{\Delta w \to 0} \sum_{n=-\sim}^{\sim} \Delta W.F(iWn).e^{iwnt}$$
$$= \int_{-\sim}^{\sim} F(t)e^{iwnt}dw \quad \text{..........(b.10)}$$

and

$$F(iw) = \lim_{\Delta w \to 0} F(iwn)$$
$$= \lim_{\Delta w \to 0} \frac{1}{2\pi} \int_{-T/2}^{T/2} f(t)e^{-iwnt}dt$$
$$= \frac{1}{2\pi} \int_{-\sim}^{\sim} f(t)e^{-iwnt}dt \quad \text{..........(b.11)}$$

Equation (B.9) and (B.10) are the inverse Fourier transform, so that the Fourier spectrum becomes:

$$SF = 2\pi|F(iw_n|$$
$$= \left|\int_{-\sim}^{\sim} f(t)e^{-iwnt}dt\right|$$
$$= \sqrt{(\int_{-\sim}^{\sim} f(t).Cos\, wt\, dt)^2 + (\int_{-\sim}^{\sim} f(t).Sin\, wt\, dt)^2}$$
$$= \pi\sqrt{Aw^2 + Bw^2} \quad \text{..........(b.12)}$$

Based on the requirement, then it is possible to define f (t) in (0, t) and outside this interval f (t) = 0, so the above requirement becomes:

$$SF = \sqrt{(\int_0^t f(t)Cos\, wt\, dt)^2 + (\int_0^t f(t)Sin\, wt\, dt)^2} \quad \text{..........(b.13)}$$

2. Metode Spectra Rasio

Spectral ratio method essentially compares the spectrum $A_1\omega$ with the amplitude spectrum $A_2\omega$.

$B(\omega) = \frac{A_1(\omega)}{A_2(\omega)}$ ……………………………………………..(b.14)

While in general

$A(\omega) = G(x)A_0(\omega)e^{-\alpha(\omega)x}$ ……………………………………(b.15)

With notes G (x) = 1 / x is the geometry factor

Then

$A_1(\omega) = G(x_1)A_0(\omega)e^{-\alpha(\omega)x_1}$ …………………………………(b.16)

$A_2(\omega) = G(x_2)A_0(\omega)e^{-\alpha(\omega)x_2}$ …………………………………(b.17)

So that

$B(\omega) = B_0(\omega)e^{\alpha(\omega)[(x_1x_2]}$ ……………………………………(b.18)

when written $\alpha(\omega)(x_1 - x_2) = \omega t/2Q$

or

$\ln[B(\omega)] = \ln[B_0(\omega)] - \frac{\omega t}{2Q}$

Which can be written as:

$\ln[B(\omega)] = \ln[B_0(\omega)] - \frac{\pi f t}{Q}$ ……………………………………(b.19)

Graph showing the relationship between the ratio of spectrum B (ω) against frequency f (Hz) will be a straight line with a slope-πt / Q as shown below:

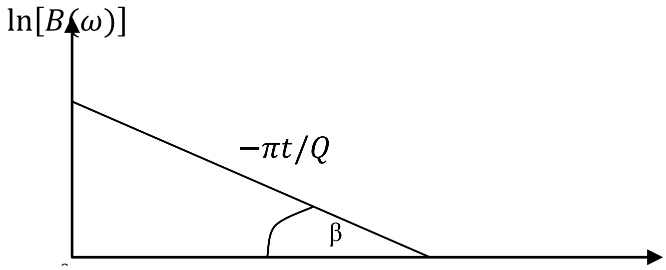


Image : Determination of the quality factor with the spectral ratio method

Thus the value of the quality factor (Q) can be calculated from

$Q = \frac{\pi t}{\beta}$ ………………………………………………….….(b.20)

With a record t is the propagation time (seconds) for a distance x1-x2 (meters) and β is the slope.

C. Methods of Data Analysis Microtremor

There are three techniques that have been developed to analyze the data to obtain values microtremor amplification factors, including :

1. Direct interpretation of the curve Fourier Spectrum or Spectrum Power (Kanai & Tanaka, 2001; Katz & Bellon, 2001)

In general, a frequency analysis method for the irregular variation of the data according to the time as microtremor, applied method Spectrum Power.

If the random variation in the data as a function of time is f (t), the Fourier transformation is described as follows :

$F(\omega) = \sqrt{An^2} + Bn^2$

Where is :

$$An(\omega) = \left(\frac{2}{T}\right)\int_0^T f(t)Cos\omega t\, dt$$

$$Bn(\omega) = \left(\frac{2}{T}\right)\int_0^T f(t)Sin\omega t\, dt \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(c.1).}$$

And the power spectrum Pn (ω) is shown by the following equation :

$$P(\varpi) = An(\varpi) + Bn(\varpi) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(c.2).}$$

Microtremor amplitude spectrum can be obtained directly through the Fourier transform is defined as follows:

$$f(t) = \frac{1}{2\pi}\int_{-\sim}^{\sim} f*(p)e^{ipt}dt$$

Where the inverse of f * (p) is:

$$f(p) = \frac{1}{2\pi}\int_{-\sim}^{\sim} f*(T)e^{ipt}dt \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(c.3).}$$

2. Period predominant interpretation to determine the amplification factor of the surface sediment layer (Kanai & Kawashumi, 2001).

Kanai and Kawashumi describes the layers of sediment soil amplification factors obtained from the calculation of the predominant period of the surface sediment layer.

Amplification factor formula described by Kanai :

$$1+\sqrt{\frac{T_o}{3}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(c.4)}$$

Where T_0 is the predominant soil period.

3. Nakamura (2000) proposed a hypothesis that microtremor vibrations at a location can be determined by calculating the spectral ratio between the horizontal component to the vertical component observed in the same location.

   The spectral ratio equations are defined as follows :

   $$Se(\varpi) = Hs(\varpi)/Hb(\varpi) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(c.5)}$$

   And the effect on the vertical component spectra are :

   $$As(\varpi) = Vs(\varpi)/Vb(\varpi) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(c.6)}$$

   Then modified spectral ratio is defined as :

   $$Sm = Se(\varpi)/As(\varpi)$$

   $$=(Hs/Hb)/(Vs/Vb)$$

   $$= (Hs/Vs)/(Hb/Vb) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(c.7)}$$

Based on experiments using the drill data, if microtremor rayleigh wave form, it can be assumed that :

$$Hb(\varpi) = Hb(\varpi)/Vb(\varpi) \approx 1$$

In a wide frequency interval, the modified spectral ratio becomes :

$$Sm(\varpi) = Hs(\varpi)/Vs(\varpi) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(c.8)}$$

D. Examples of Data Processing

The output is an average spectrum mikrotremor. From these spectra it can be seen:

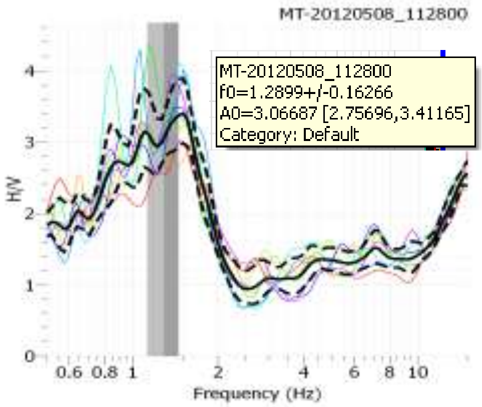
1. Analysis of Spectral ratio (SR) which is Amplification Factor (AF) based on interpretation Nakamura, from microtremor spectral peaks coordinate value (A) at the measurement location, the equation is:

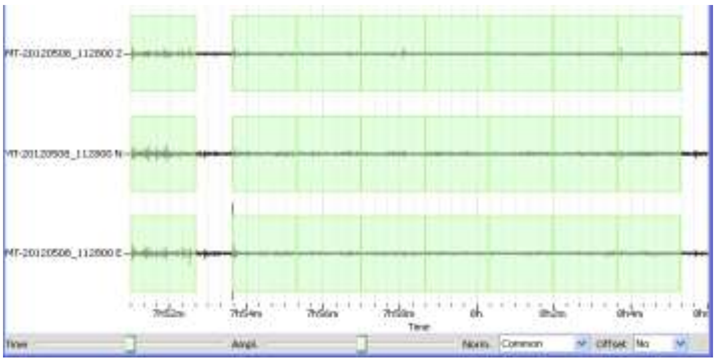
   SR = S_H/S_V = $Sm(\varpi) = Hs(\varpi)/Vs(\varpi)$.

2. Resonance frequency (f dom) and microtremor spectral peaks (A). From this value, we can determine the predominant period (T dom) based on interpretation of Kanai and Tanaka (equation (c.1) - (c.3)), and the amplification factor (AF) of interpretation Kanai & Kawashumi (equation (C.4)). As an example of data processing spectrum analyzer is as follows:

Kurve Spektrum TP-1 ; lokation Birowo 1. Longitude : 112.3753 ; Lattitude : 8.232 ; elevation : 306 m

ID	Name	Component	Time reference	Start time	End time	Sampling frequency	dt	N samples	Duration	Rec x	Rec y	Rec z	Type
1	MT-20120508_112800	Vertical	27/03/2009 00:00:00	7h51m	8h6m	100	0.01	90000	15m	0	0	0	Waveform
2	MT-20120508_112800	North	27/03/2009 00:00:00	7h51m	8h6m	100	0.01	90000	15m	0	0	0	Waveform
3	MT-20120508_112800	East	27/03/2009 00:00:00	7h51m	8h6m	100	0.01	90000	15m	0	0	0	Waveform





From the data generated Nakamura calculation of spectral ratios of 0.808, the predominant period (T) 0.775 sec, and amplification factor (AF) based on the predominant interpretation Kanai period of 1.293.

E. Analysis and Interpretation of Data

The data obtained were classified based classification Kanai, predominant period value indicates the type of soil is soil classification type 4 (Kanai) and type C (Omote - Nakajima) with a description of the land is soft alluvial soil, and complex formation. Then conducted comparison analysis based amplification factor Interpretation Kanai and Nakamura. Based on the results obtained amplification factor, it can be interpreted that at that point showed instability in the surface layer of a mining area. If viewed in terms of its structure, this location is not stable due to the oblique surface layer (slope), so that the occurrence of landslide and fault generated high enough.

CONCLUSION AND SUGGESTION

The concept and application of mathematics can be applied to disaster risk management, that is the application Fourier series and Fourier Specrum in Microtremor analysis, determination of this spectrum is used as the basis for analysis of spectral ratio (SR) which is the amplification factor (AF) based on interpretation Nakamura, and the predominant period (T dom) based interpretation Kanai. Based on the results obtained amplification factor, can be obtained by interpretation of the existence of the condition of the surface layer of soil instability.

In order for the management of disaster risk management more leverage, need to be developed to make the data processing system design decisions of the system information, for example by using the approach of ANP (Analytical Network Processing). So it can be mapped proneness and not.

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