UAD Universitas Ahmad Dahlan

Mathematical Scientific Journal
Vol. 10, No.2, October 2023, pp. 68-74
ISSN 2774-3241
http://journal.uad.ac.id/index.php/Konvergensi

Batik Motifs From Mathematical Model Of Earthquake Waves And Kartini Reactor

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Received: *Revised:* *Accepted:*

KEYWORDS

Batik Motif
Mathematical Model of Earthquake Waves
Kartini Reactor
Motif Philosophy

ABSTRACT

The batik motif from the mathematical model of earthquake waves and the Kartini Reactor is an innovation in the world of batik that combines elements of art and science. Earthquake waves are complex physical phenomena that occur as a result of the release of energy from earthquake sources that propagate through the layers of the earth in seismic form. The mathematical modeling used to understand the dynamics of wave propagation is partial differential equations and numerical simulation methods. In addition, this research highlights the role of Raktor Kartini, a nuclear reactor located in Yogyakarta, for the development of science and technology in Indonesia. In this research, the earthquake wave propagation pattern and the dynamics of the Kartini Reactor are translated into batik motifs, creating a visual representation of scientific concepts. This approach not only enriches the cultural heritage of batik, but also introduces science to the public. The philosophy of this motif emphasizes the balance between resilience and flexibility, reflecting how technological systems must adapt to dynamic environmental conditions.

Introduction

Earthquake waves are complex physical phenomena, where the energy from the earthquake source spreads through the layers of the earth in the form of seismic waves. Understanding the wave propagation pattern is crucial for various applications, such as disaster mitigation, design of earthquake-resistant structures, and geophysical exploration. The characteristics of these waves are influenced by the mechanical properties of the earth's materials which tend to be heterogeneous and anisotropic, as well as by the interaction between layers in the earth's crust.

Mathematical models have a significant role in analyzing the dynamics of earthquake wave propagation. These models utilize partial differential equations and numerical simulation methods to predict seismic wave behavior under various geological conditions. Through such models, it is possible to gain insights into how seismic waves travel, reflect, and refract within complex subsurface structures.

Kartini reactor, a TRIGA (Training, Research, Isotope Production, General Atomics) nuclear research reactor located in Yogyakarta, has a strategic role in supporting the advancement of science and technology in Indonesia. Functioning as a research, education, and isotope production facility, this reactor was designed with priority on safety and operational flexibility. As a low-power reactor, the study of the Kartini Reactor often involves the analysis of reactor physics, thermal dynamics, and structural response to various environmental conditions, including the threat of earthquakes.

To ensure its reliability and efficiency, mathematical modeling and numerical simulation are indispensable tools in studying the physical dynamics of this reactor. This research aims to develop analytical and numerical methods to evaluate the performance of the Kartini Reactor, both in terms of safety and operational effectiveness, with the hope of contributing to the development of national nuclear reactor technology.

This research focuses on the development of mathematical models that can accurately represent earthquake wave propagation patterns. In addition, the study aims to evaluate the influence of material parameters and the configuration of the earth's layers on wave dynamics. Specifically, it seeks to apply these models to assess the performance and safety of the Kartini Reactor under seismic loading, thereby supporting risk mitigation efforts and contributing to the development of national nuclear reactor technology.

Methods

This study is a numerical investigation aimed at analyzing the vibration of earthquake waves on multi-storey buildings through a mathematical modeling approach. The data used are obtained from literature reviews and numerical simulations, incorporating physical parameters of the buildings such as mass, stiffness, and damping coefficients. The mathematical model is formulated as a system of nonlinear differential equations based on Newton's second law, describing the relationship between acceleration, velocity, and displacement with respect to external forces acting on each floor. Data collection involves adopting parameters and equations from relevant studies, including the work of [1]. The data are processed through mathematical modeling and solved numerically using differential methods, taking into account stiffness forces, damping forces, and external loads. Conclusions

 ISSN 2774-3241

are drawn by analyzing the dynamic responses of each floor to seismic excitation, presented in the form of displacement, velocity, and acceleration graphs over time, to provide insights into the structural behavior under earthquake loading.

Result and Discussion

1. Kartini Reactor

In Figure 1, the vibration wave caused by the release of energy from the center of the earthquake that reaches the earth's surface is called an earthquake. The wave propagates to the surface of the ground so that it makes the building on top vibrate. In this case, we will calculate the vibration of earthquake waves against buildings above the surface of the earth. Based on the results of the research that has been done, it was concluded that the mathematical model of the effect of earthquakes on high-rise buildings is in the form of a non-linear differential equation that can be written as follows.

$$Mx'' = Cx' + Kx + F \tag{1}$$

where

x = Relative displacement of system mass (m)

x' = Relative velocity of system mass (m/s)

x'' = The relative acceleration of the mass of the system (m/s^2)

k = Building stiffness constant (N/m)

c = Damping coefficient (N s/m)

m = Mass of the building (kg)

F = External force acting on each floor of the building

In accordance with Newton's Second Law, the resulting force acting on each floor of a building is formed, resulting in the following equation.

1. Equation of balance of floor dimension 1

$$m_1\, x_1'' = -k_1x_1 + k_2(x_2 - x_1) - c_1(x_1' - x_2') + m_1A\omega^2\cos\omega t \tag{2}$$

2. Equation of balance of the dimensions of the 2nd floor

$$m_2\, x_2'' = -k_2(x_2 - x_1) - k_3(x_3 - x_2) - c_1(x_2' - x_1') - c_2(x_1' - x_3') + m_2A\omega^2\cos\omega t \tag{3}$$

3. The balance equation of the 3rd floor dimension

$$m_3\, x_3'' = -k_3(x_3 - x_2) - k_4(x_4 - x_3) - c_2(x_3' - x_2') - c_3(x_3' - x_4') + m_3A\omega^2\cos\omega t \tag{4}$$

In general, the dimensional balance equation of each floor can be written in the form

 ISSN 2774-3241

$$\sum F_x = F_{Ki} + F_{Ci} + F_{ti} \quad (5)$$

where

F_{Ki} = stiffness force on the i-th floor

F_{Ci} = damping force on the i-th floor

F_{ti} = exterior style that works on the i-th floor

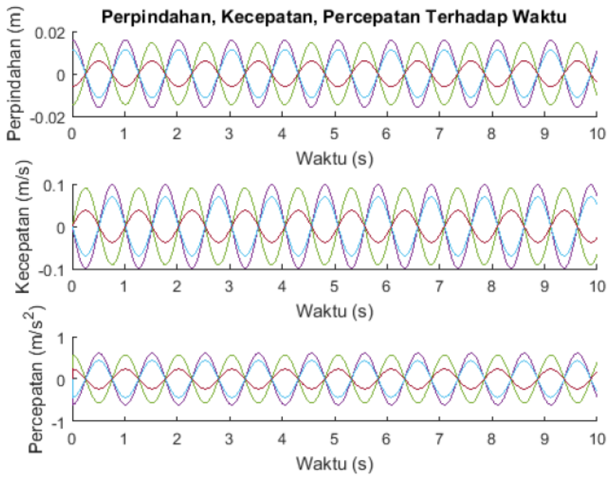

Figure 1. Displacement, Velocity and Acceleration Against Time [1].

a. Meaning of Earthquake Wave Philosophy

Batik with an earthquake motif contains a deep philosophy of resilience and harmony with the power of nature. In traditional Indonesian batik art, this motif often combines elements that describe the strength and beauty of the natural phenomenon. Batik with the earthquake motif symbolizes the way people respond to sudden changes, facing challenges with calmness and creativity. The motifs displayed often depict movement and dynamics that describe the tremors of the earthquake, as well as the hope for recovery and renewal. Thus, batik gempa becomes more than just a work of art, but a philosophical symbol that reflects resilience, strength, and beauty in the face of uncertainty.

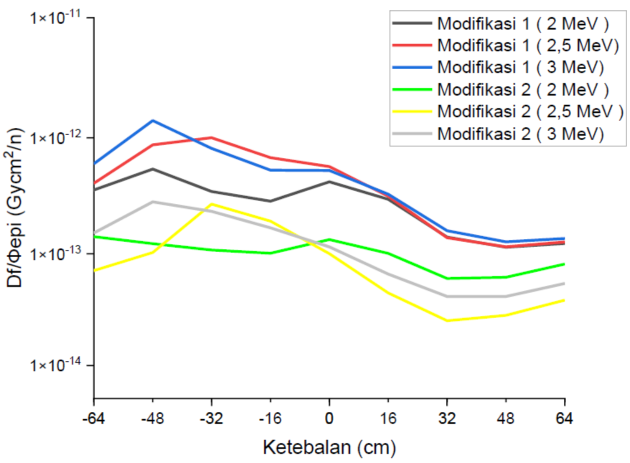

Figure 2. $Df/\Phi epi$ against thermal column thickness [2]

2. Kartini Reactor

The design of the thermal column in the reactor was developed to ensure that the reactor output parameters meet the standards set by the IAEA (International Atomic Energy Agency), such as neutron flux distribution and gamma ray dose rate. This research proposes to modify the thermal column design of the Kartini reactor computationally using the Monte Carlo method with the Particle and Heavy Ion Transport Code System (PHITS) software. In this simulation, the material used for the thermal column is 16 cm Ai, 12 cm Pb, 15 cm Ni, and 87 cm graph in the first modification, as well as 87.0 cm, 74.5 cm, and 61.5 cm in the second modification. The applied neutron energy is 2 MeV, 2.5 MeV, and 3 MeV. The simulation results of the design modification were analyzed for epithemal neutron flux parameters, fast neutrons, gamma dose, thermal and epithemal flux ratio, and the ratio between neutron current and total neutron flux. The second modification with energy 2 MeV and 2.5 MeV showed the best results, with an epithemal neutron flux of 1.78×10^9 n/cm^{2}s and 1.46×10^9 n/cm^{2}s, and a gamma dose of 1.72×10^(-13) Gycm^2/n and 1.91×10^(-13) Gycm^2/n, which meets the IAEA requirements.

a. Meaning of Kartini's Reactor Philosophy

The philosophy of batik motifs inspired by nuclear reactors depicts an effort to integrate traditional elements with modern technology and scientific complexity. Batik motifs that refer to nuclear reactors often combine designs that describe the energy, structure, and dynamics of nuclear reactions with the aesthetic value of batik that is full of meaning. This philosophy reflects the fusion between cultural heritage and technological progress, showing how society strives to utilize advanced technology while still respecting and preserving tradition. In addition, the nuclear reactor batik motif also symbolizes the potential and risks of nuclear energy, implying a balance between innovation and responsibility, as well as the ethical and environmental challenges that arise in the application of the technology. Thus, the nuclear reactor batik motif not only combines the beauty of batik, but also presents an in-depth reflection on scientific progress and its impact on society and the environment.

3. Insert Process

The batik process is as follows.

a. The process of drawing motifs on tracing paper (Figure 3)

b. The process of drawing motifs on Primisima fabric.

c. Batik process. Figure 4 is a finished batik motif.

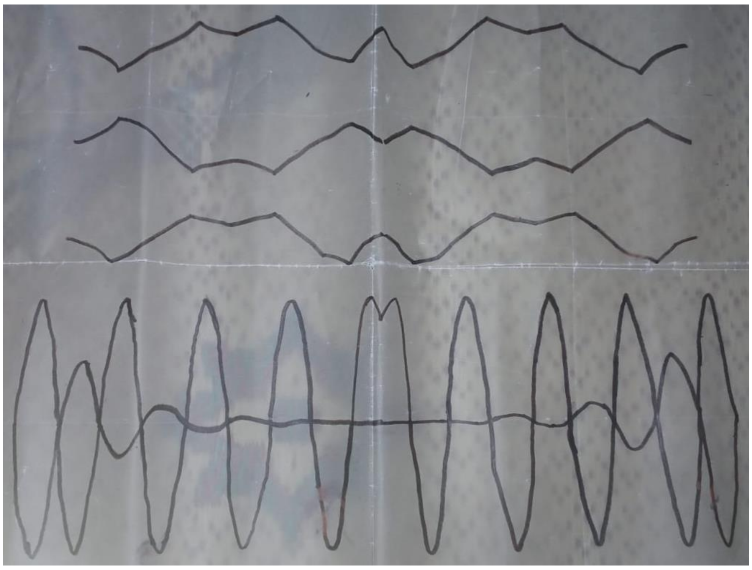

Figure 3. Batik motif on paper

Figure 4. Earthquake and Neutron in Batik Motif

Conclusion

This research has shown that mathematical models can be used as a basis in the development of batik motifs based on natural phenomena and technology. By applying mathematical principles such as differential equations and numerical simulation, earthquake wave patterns can be accurately represented in batik designs. The same is the case with the Kartini Reactor dynamics pattern, which is visualized in motifs that reflect the interaction of energy in the nuclear reactor system. From a philosophical perspective, this motif teaches the importance of resilience, balance, and adaptation to environmental changes, both in the context of nature and technology. This batik not only functions as an artistic expression but also as an educational medium that bridges the world of art and science to the future. This research can be expanded by developing more complex models and expanding collaboration between scientists, batik artists, and textile designers in order to produce increasingly innovative and highly competitive motifs.

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