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# ANALYSIS OF THE IMPACT OF FUEL OIL PIPING SYSTEM SUPPORT ON THE VIBRATION

**Tengku Nur Farwizah Tengku Mohd Fozi[1], Roslin Ramli[1*], Nur Azimah Mohd Azil[1], Nik Norfara Idayu Mohd Zain[1] and Septia Hardy Sujiatanti[2]**

[1] *Maritime Engineering Technology, Universiti Kuala Lumpur Malaysian Institute of Marine Engineering Technology, Lumut, Perak, Malaysia.*
[2] *Department of Naval Architecture, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia*
[*] *roslin@unikl.edu.my*

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## ABSTRACT

*Vibration in pipelines is often an underestimated aspect in the design and construction of piping systems, particularly within multi-purpose offshore vessels where fuel lines are critical to operational reliability and safety. This study investigates the impact of piping system support on reducing vibration in the design and construction of piping systems. This study provides simulation-based insights that demonstrate optimised support configurations to significantly enhance the structural integrity and operational safety. Previous studies have predominantly focused on pipeline vibration in isolation, without integrating the structural role of support systems. This study fills the gap by integrating piping support design with vibration mitigation in the fuel oil piping systems. The simulation approach utilises pipe software to simulate various support configurations and evaluate their effectiveness in reducing vibration. Comparative simulations were conducted between an existing model with minimal support and an optimised model with additional support. The results indicate that strategically placed supports can significantly reduce both vibration amplitudes, thereby enhancing structural integrity and reducing the risk of mechanical failure. This study reveals that the simulation-based approach not only bridges a critical research gap but also provides practical insight and design guidance for marine engineers and pipeline designers. The findings can serve as a reference framework for future studies and the development of support strategies aimed at improving the durability and performance of piping systems in harsh offshore environments.*

## 1. Introduction

Piping vibration remains a frequently underestimated factor in the design and construction of piping systems, particularly in multi-purpose offshore vessels where fuel lines play a vital role in ensuring operational reliability and safety (Zachwieja, 2017). These vessels rely heavily on complex fuel line networks that operate under varying flow conditions and space constraints.

Prior studies have largely focused on vibration phenomena in isolation, neglecting the interdependent relationship between piping support structures and vibration mitigation, especially in static and dynamic analysis. For example, Frequency factors for calculating the mechanical natural frequencies for the classical piping configurations (uniform straight beams) and various piping bend configurations are presented by J.C. Wachel (Wachel & Szenasi, 1993). This study addresses that gap by investigating the role of support configuration in reducing vibration within the fuel oil piping system on multi-purpose offshore vessels.
This study seeks to contribute new insights into piping system design. A piping software simulation-based approach is utilised to analyse designs to reduce vibration of the fuel oil piping system for multi-purpose offshore vessels. A comparative analysis between a baseline model with minimal support and an optimised model with strategic additional supports highlights the impact of support design on vibration control (El-Borgi et al., 2021; Wicaksono & Subekti, 2021).

The results were ambiguous. Based on previous studies, the results of the comparative analysis between the existing model and the optimised model depict a significant change in the vibration of the pipe in fuel lines (Chen, 2023; Rao, Maiya, Prabhu, Santhosh, & Hebbar, 2021; Zahra, Supomo, & Baihaqi, 2020). In addition, studies also show that the conditions for the stability of pipe vibrations depend on the support used (Fischer, Cagliyan, & Neidel, 2014; Zachwieja, 2017). The cause of vibrations of straight supported pipes is due to excitation by the medium flow. This medium flow is characterized by high amplitude, and vibration occurs if the flow velocity exceeds the critical velocity.

## 2. Methodology

This study adopts a simulation-based approach to analyse the impact of piping configurations on vibration behaviour in the fuel line on board multi-purpose offshore vessels. The approach consists of three main phases.

### 2.1 Interpretation of Process and Instrumentation Diagrams (P&IDs)

The initial phase of the study focused on a thorough analysis of the Process and Instrumentation Diagram (P&ID) for the vessel's fuel oil transfer system. Within this system, specific fuel lines were selected due to their critical role in ensuring reliable fuel transfer operations and their susceptibility to mechanical and dynamic loading conditions. This careful selection provided a foundation for subsequent modelling and vibration analysis, targeting the most vulnerable and operationally significant sections of the piping network.

### 2.2 Development of piping system models with varying support arrangement

Based on data obtained from Table 1, two distinct piping models were developed within Bentley AutoPIPE Advanced to conduct a comparative analysis:

- Model A – Baseline model
- Model B – Optimized model

Model A serves as the baseline configuration, reflecting the original support arrangement as specified in the P&ID. In contrast, Model B incorporates additional strategically placed supports aimed at reducing vibration and optimizing the overall system performance. This modelling approach enables a clear evaluation of the impact that enhanced support configurations have on vibration mitigation within the piping network.

### 2.3 Simulation of vibration of the piping system

In the final phase, a comprehensive dynamic analysis was conducted to assess the vibration behaviour of both models under typical operational conditions experienced by offshore vessels. The simulation process encompassed both static and displacement analyses, enabling a detailed evaluation of the piping system's response to various mechanical and dynamic loads. This approach provided critical insights into the effectiveness of the support configurations in mitigating vibration and enhancing structural integrity.

## 3. Results

The results section is structured into three main parts. First, the process and instrumentation diagram (P&ID) is presented to provide a detailed overview of the piping system layout. Next, the development of comprehensive piping system models is described, highlighting the parameters and assumptions used. Finally, the simulation results of the piping system's vibration behaviour are analysed to assess performance and validate the models.

### 3.1 Process and Instrumentation Diagram (P&ID)

The Process and Instrumentation Diagram (P&ID) serves as a foundational element in understanding the fuel oil piping system within multi-purpose offshore vessels, as shown in Table 1. The P&ID provides a detailed schematic representation of the piping layout, including the locations of supports, valves, and instrumentation critical for monitoring and controlling fluid flow. It highlights the strategic placement of pipe supports, which are essential for mitigating vibration and ensuring structural stability under dynamic marine conditions. This diagram not only facilitates the development of accurate piping system models but also guides the simulation process by clearly defining the physical and operational parameters that influence vibration behaviour. Through the P&ID, the study effectively links theoretical design considerations with practical system configurations, enabling a comprehensive analysis of

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vibration mitigation strategies.

Table 1: Process and Instrumentation Diagram

| **Component** | | | |
|---|---|---|---|
| Component | Type | Pressure | |
| Valve | Swing Check Valve | 300 | |
| Flange | Slip-On | 300 | |
| **Piping and Tank** | | | |
| Pipe ID | Type material | Nominal (inch) | Actual OD (inch) |
| 3″ STD | A106-B | 3 | 3.5 |
| 6″ STD | A106-B | 6 | 6.625 |
| 18″ STD | A106-B | 18 | 18 |
| 20″STD | A106-B | 20 | 20 |
| 22″STD | A106-B | 22 | 22 |
| 28″STD | A106-B | 28 | 28 |
| 30″STD | A106-B | 30 | 30 |
| 34″STD | A106-B | 34 | 34 |
| **Support** | | | |
| Type | Symbol | Nominal (inch) | |
| Spring | Hanger | 3 | |
| V-Stop | Rod Hang | 3 | |
| Guide | - | 3 | |

## 3.2 Development of Piping System Models

The development of the piping system models in this study involved a systematic approach to accurately represent the fuel oil piping network on multi-purpose offshore vessels. Starting from the detailed P&ID, the models incorporated key physical and operational parameters, including pipe geometry, material properties, and support configurations, as shown in Figure 1. Advanced computer modelling techniques were employed to simulate the dynamic behaviour of the piping system, capturing the nonlinear interactions between pipe vibration and support placements. The models were designed to reflect realistic marine conditions, enabling the evaluation of vibration mitigation strategies through virtual simulations. This approach not only facilitated the validation of theoretical vibration analyses but also provided a practical framework for optimizing support designs to enhance structural integrity and system reliability.

Model A, designated as the baseline model, is developed based on the original support configuration of the fuel oil piping system in the multi-purpose offshore vessel (MOPSV) as shown in Figure 2. This model reflects the existing design parameters and support placements as implemented in the vessel's operational setup. By maintaining the initial support layout, Model A serves as a reference point to evaluate the system's vibration behaviour under typical marine conditions. The baseline configuration allows identification of inherent vibration issues and structural vulnerabilities associated with minimal support strategies, providing a critical foundation for subsequent optimization and comparative analyses.

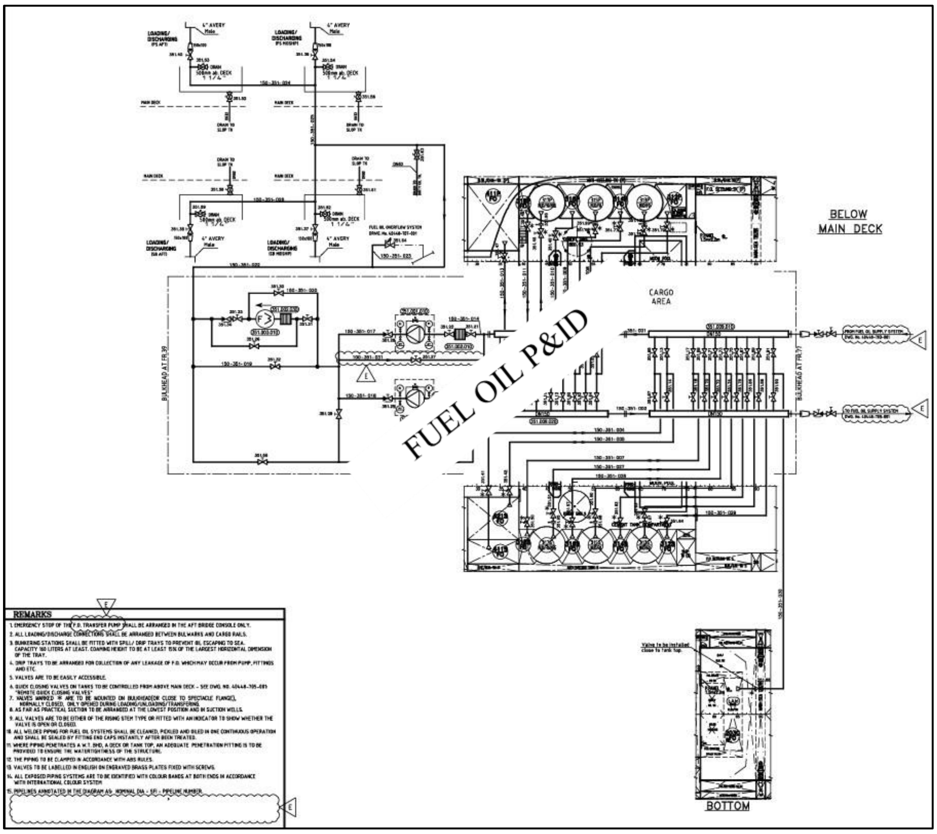


Figure 1. Fuel oil piping system MPOSV

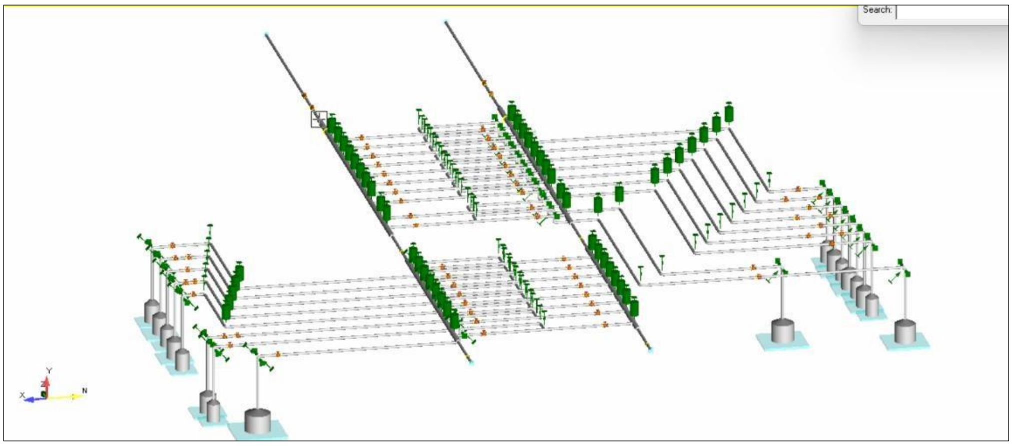


Figure 2. Model A - Baseline model

## 3.3 Simulation Vibration of Piping System

The simulation of vibration in the piping system was conducted using advanced finite element modelling techniques to capture the dynamic response of the fuel oil piping under realistic offshore operating conditions. The simulations incorporated flow-induced and acoustic-induced vibration phenomena, reflecting the complex interactions between fluid flow, pipe geometry, and support configurations. By analysing vibration amplitudes and frequency spectra, the study identified critical vibration modes and hotspots that could lead to mechanical fatigue and potential failure. The results demonstrated that strategic adjustments in support placement significantly reduce vibration levels, thereby enhancing structural integrity and system reliability. This approach not only validated theoretical frequency factor calculations but also provided practical insights for optimizing piping system designs in multi-purpose offshore vessels.

Model A represents the baseline piping system model, which replicates the original support configuration as detailed in the Process and Instrumentation Diagram (P&ID) of the multi-purpose offshore vessel (MOPSV) as shown in Figure 3. In this model, the supports are positioned according to the existing design without any modifications. Simulation results for Model A reveal higher vibration frequency throughout the piping system, as indicated the value of frequency, which is 50.9289 Hz. This high vibration intensity highlights the susceptibility of the original support layout to excessive dynamic stresses, which may contribute to mechanical fatigue and compromise system integrity under offshore operating conditions.

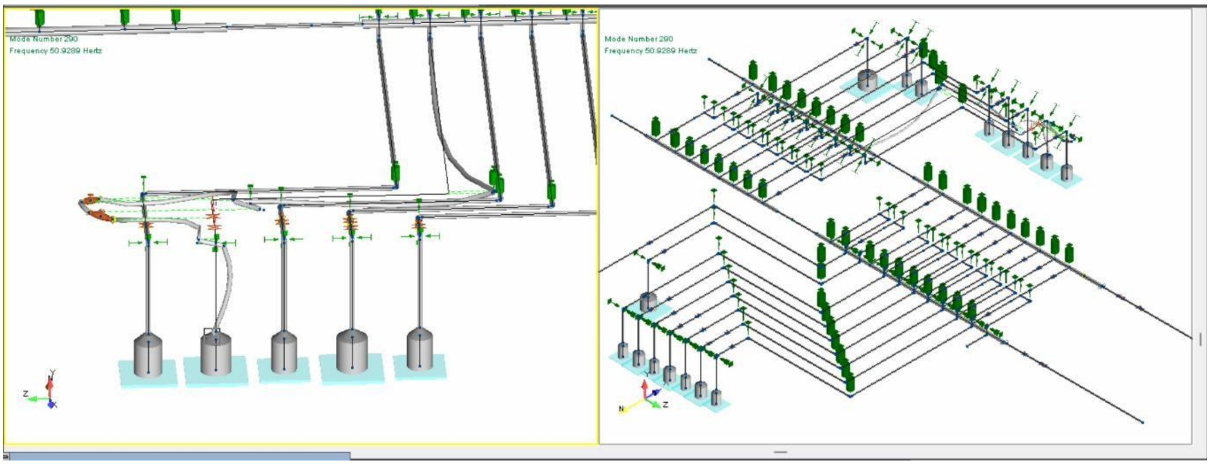

Figure 3. Model A simulates vibration

In contrast, Model B incorporates additional supports strategically placed to enhance the system's vibration resistance. The simulation of Model B shows a marked reduction in vibration frequency, which is 10.6119 Hz, signifying a lower vibration frequency. These results demonstrate the effectiveness of optimized support configurations in mitigating vibration, thereby improving the structural performance and reliability of the fuel oil piping system. The comparative analysis between Models A and B underscores the critical impact of support design on vibration control and thus validates the practical benefits of targeted support enhancements in offshore piping applications.

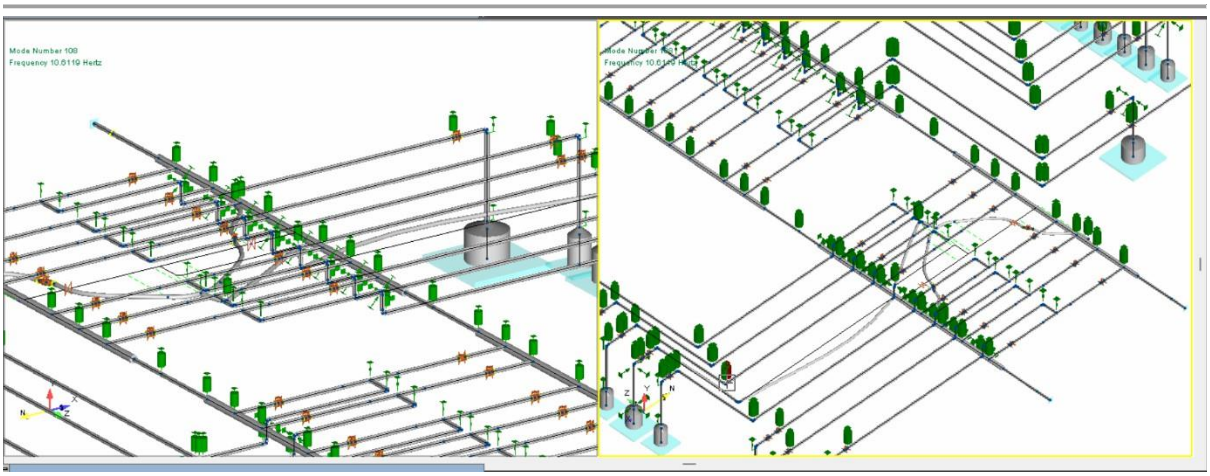


Figure 4. Model B simulates vibration load

## 4. Discussion

The comparative analysis between the baseline model (Model A) and the optimized model (Model B) reveals a marked reduction in pipe vibration achieved through carefully designed support configurations. The reduction of vibration frequency percentage is 79% between Model A and Model B. This finding aligns with the conclusions of Beniamin and Niordson, who emphasized the critical role of support design in ensuring pipe vibration stability. The notable difference in vibration amplitude observed between the two models not only validates Wachel's frequency factor calculations but also extends these theoretical insights into practical applications within the fuel oil piping systems of multi-purpose offshore vessels.

This study addresses a significant gap in existing studies by connecting isolated vibration analyses with integrated support system design. It highlights the intricate relationship between support placement and vibration mitigation in the challenging marine environment. Simulation results demonstrate that even small adjustments in support locations can lead to substantial improvements in both system performance and structural integrity. These insights carry important implications for the design of new vessels and the retrofitting of existing piping systems.

The findings also call into question the adequacy of traditional minimal support designs, which appear insufficient to guarantee the long-term reliability of fuel oil piping systems operating under dynamic offshore conditions. The vibration patterns identified in the baseline model suggest a heightened risk of mechanical fatigue and potential failure, underscoring the need for more robust support strategies.

Overall, this study contributes valuable empirical evidence toward the development of enhanced design criteria for offshore fuel oil piping systems. It lays a foundation for future work that should include physical validation tests and explore alternative support types and materials to further optimize vibration control. By bridging theory and practice, this study advances the engineering of safer and more reliable marine piping infrastructures.

## 5. Conclusion

This study demonstrates that optimized support configurations significantly reduce vibration in fuel oil piping systems on multi-purpose offshore vessels. The comparative simulation analysis revealed substantial differences in vibration amplitudes between conventional minimal support arrangements and strategically designed support systems. These findings bridge the critical gap in integrating support design with vibration mitigation in marine environments, as the study provides evidence that modest modifications to support placement enhance structural integrity and system performance. The results have practical applications for new vessel designs and existing system retrofits, potentially extending operational lifespan and improving safety. This research establishes a methodological framework that contributes to more robust design criteria for fuel oil piping systems in offshore vessels, with implications for improved operational efficiency and reduced maintenance requirements in maritime operations.

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## Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the author(s) used OpenAI's ChatGPT to assist in improving the readability and language of the text. All content generated by ChatGPT was subject to thorough review, editing, and revision by the author(s) to ensure its accuracy, completeness, and alignment with the research objectives. The author(s) take full responsibility for the integrity and content of the published work. This declaration complies with ICGESD 2025 guidelines on the use of generative AI in scientific writing.

## References

Chen, R. (2023). Main Steam Pipeline Support Hanger Failure and Pipeline Vibration Treatment. *Advances in Engineering Technology Research, 8*(1). https://doi.org/10.56028/aetr.8.1.114.2023

El-Borgi, S., Alrumaihi, A., Rajendran, P., Yazbeck, R., Fernandes, R., Boyd, J. G., & Lagoudas, D. C. (2021). Model updating of a scaled piping system and vibration attenuation via locally resonant bandgap formation. *International Journal of Mechanical Sciences, 194*. https://doi.org/10.1016/j.ijmecsci.2020.106211

Fischer, B., Cagliyan, E., & Neidel, A. (2014). Metallurgische Fehleruntersuchung einer kleinen Leckage an einer Heizölrückleitung einer Kombizyklus-Gasturbine. *Praktische Metallographie/Practical Metallography*, *51*(5). https://doi.org/10.3139/147.110252

Rao, R. N., Maiya, M., Prabhu, S., Santhosh, G., & Hebbar, G. (2021). The analysis of a piping system for improvement of a system in a process unit. *Materials Today: Proceedings*, *46*. https://doi.org/10.1016/j.matpr.2021.02.595

Wachel, J. C., & Szenasi, F. R. (1993). Analysis of torsional vibrations in rotating machinery. *Proceedings of the Twenty-Second Turbomachinery Symposium*.

Wicaksono, F., & Subekti, S. (2021). Analisis Pengaruh Penyumbatan Aliran Fluida pada Pipa dengan Metode Fast Fourier Transform. *Jurnal Dinamika Vokasional Teknik Mesin*, *6*(1). https://doi.org/10.21831/dinamika.v6i1.36339

Zachwieja, J. (2017). Stress analysis of vibrating pipelines. *AIP Conference Proceedings*, *1822*. https://doi.org/10.1063/1.4977691

Zahra, A. K., Supomo, H., & Baihaqi, I. (2020). Analisis Teknis dan Ekonomis Penerapan Pipe Piece Family Manufacturing (PPFM) pada Instalasi Sistem Perpipaan Kapal Tanker 17.500 DWT. *Jurnal Teknik ITS*, *8*(2). https://doi.org/10.12962/j23373539.v8i2.47463