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Advancements in Wheel Over Point Calculations: Enhancing Navigational Safety and Efficiency

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Abstract - The manoeuvrability of single-propeller vessels is essential in maritime activities, especially in narrow waterways. The "wheel over point," a crucial characteristic for manoeuvring, guarantees secure and effective navigation. This study examines the theoretical and practical ramifications of the subject, with a focus on contemporary technological breakthroughs. Hydrodynamic models and computational fluid dynamics (CFD) simulations have enhanced the accuracy of wheel-over-point estimates by including elements such as water resistance and external disturbances. The efficacy of real-time data systems in improving vessel manoeuvring is demonstrated by their practical use in crowded ports. Technological progress, such as the development of AI and machine learning, improves the capacity to make predictions and helps to increase fuel economy and promote sustainability. Simulation tools, virtual reality (VR), and augmented reality (AR) offer extensive training platforms for those working in the marine industry. Future research should prioritise the development of adaptive navigation systems and the integration of real-time data to enhance navigational safety and operational efficiency.

Keywords: Wheel over point, single propeller vessel, maneuverability, computational fluid dynamics, navigational safety

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1.0 INTRODUCTION

The navigation of single propeller vessels presents unique challenges, particularly concerning maneuverability in restricted water. The "wheel over point" refers to the precise location at which a vessel initiates a turn to follow a planned trajectory accurately (Kamis, Ahmad Fuad, Ashaari, & Mohd Noor, 2021). This review aims to dissect the intricacies of the wheel over point, emphasizing its importance in maritime navigation and safety.

Recent studies have highlighted the critical nature of maneuvering parameters in preventing maritime accidents (Yaacob et al., 2014). Effective maneuvering strategies are essential to avoid collisions, particularly in confined and heavily trafficked waterways (Chauvin et al., 2013; Omelchenko & Petrichenko, 2020). Accurate determination of the wheel over point can significantly reduce the risk of groundings and collisions, contributing to safer maritime operations (IMO ISM, 2018; Kamis, Ahmad Fuad, Ashaari, & Mohd Noor, 2021).

The advent of advanced simulation tools and real-time monitoring technologies has further enhanced the precision of these maneuvers. For instance, modern ship simulators allow for testing of theoretical models and provide real-time feedback, improving the accuracy of wheel over point determinations (Kuznetsov et al., 2021; Zhu et al., 2014).

The wheel over point is influenced by various factors, including vessel speed, turning radius, and hydrodynamic forces. Understanding these factors is essential for navigators and maritime engineers to optimize vessel performance and ensure safe passage through narrow channels and busy ports (Kamis et al., 2022; Sahin, 2016). This review synthesizes recent research findings and integrates them with established maritime practices. By exploring both theoretical frameworks and practical applications, the article provides a comprehensive overview of the wheel over point's role in single propeller vessel navigation (Kamis, Ahmad Fuad, Ashaari, & Mohd Noor, 2021).

Table 1: Factors Influencing Wheel Over Point Determination

Factor	Description	Source
Vessel Speed	Speed at which the vessel is traveling	(Kamis, Ahmad Fuad, Ashaari, & Mohd Noor, 2021; Lee, 2012)
Turning Radius	Radius of the vessel's turn	(Kamis, Ahmad Fuad, Ashaari, & Mohd Noor, 2021; Muscari et al., 2017)
Hydrodynamic Forces	Forces acting on the vessel from water resistance and propulsion	(Faltinsen, 2006)
External Disturbances	Impact of wind, currents, and waves	(Lee et al., 2015)

2.0 Theoretical Framework and Hydrodynamic Considerations

The theoretical foundation of the wheel over point is grounded in the principles of ship hydrodynamics and control theory. The interaction between a vessel's hull, propeller, and rudder plays a pivotal role in determining its maneuvering characteristics (Muscari et al., 2017) as seen in Figure 1.

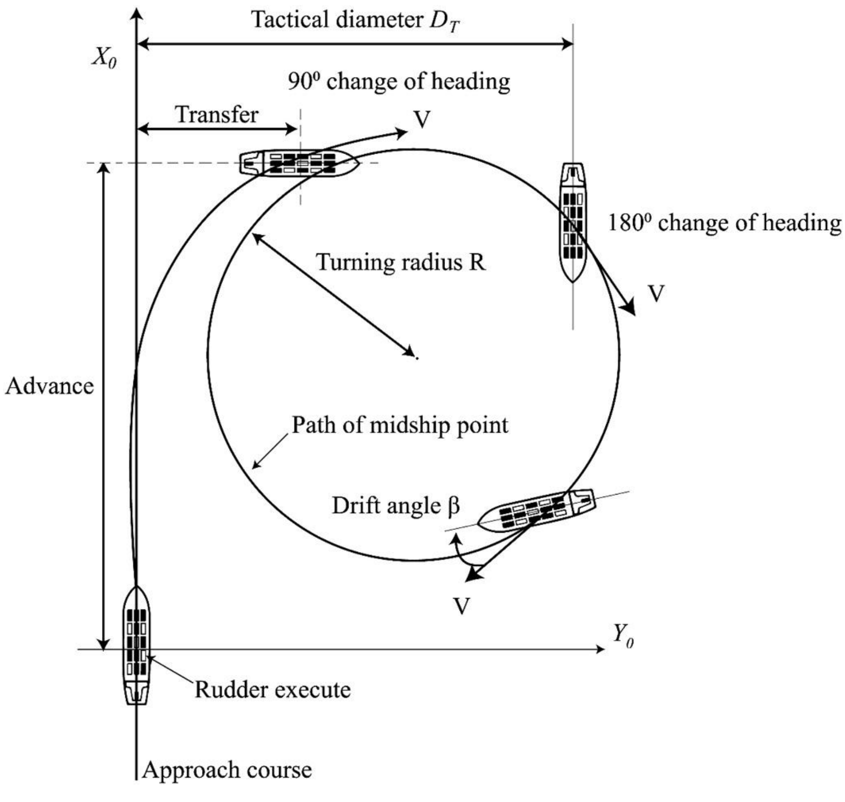

Figure 1: Maneuvering characteristic of a ship (ITTC, 2002)

Hydrodynamic models have been extensively developed to predict the behavior of single propeller vessels under various conditions. These models consider various factors such as the effects of water resistance, propulsion forces, and external disturbances like wind and current. Recent advancements include detailed computational fluid dynamics (CFD) simulations that have significantly improved the accuracy of these predictions (Razaghian et al., 2021; Roshan et al., 2020). These models consider the effects of water resistance, propulsion forces, and external disturbances such as wind and current (Y. Liu et al., 2021). Advanced computational fluid dynamics (CFD) simulations have enabled more accurate predictions of these interactions, aiding in the precise calculation of wheel over points (Villa et al., 2020).

Empirical studies have provided valuable insights into the practical aspects of maneuvering. Field experiments using scale models and full-scale trials have validated theoretical predictions and highlighted the importance of contextual factors such as water depth and vessel loading (Wang et al., 2020). These findings underscore the complexity of determining the wheel over point and the need for comprehensive modeling approaches (Miyazaki et al., 2001).

Moreover, recent advancements in sensor technologies and real-time data analytics have revolutionized maritime navigation. Integrated navigation systems that utilize GPS, AIS, and sonar data provide continuous monitoring and adjustment of wheel over points, enhancing navigational accuracy and safety (J. Liu & Hekkenberg, 2017).

2.1 Technological Advancements and Simulation Tools

Technological advancements have significantly impacted the study and application of wheel over points in single propeller vessels. Simulation tools, in particular, have emerged as indispensable resources for maritime training and operational planning. Modern bridge simulators offer highly realistic environments where navigators can practice maneuvers and understand the dynamics of wheel over points without the risks associated with real-world trials (Komasawa et al., 2019). These simulators incorporate detailed hydrodynamic models and real-time data inputs, providing a comprehensive training platform for maritime professionals (Nicolescu et al., 2007).

Furthermore, the integration of artificial intelligence (AI) and machine learning algorithms into navigation systems has enhanced the predictive capabilities of wheel over point calculations. AI-driven models can analyze vast amounts of historical data to identify patterns and optimize maneuvering strategies (Gunathilake et al., 2014). This technological synergy not only improves safety but also contributes to fuel efficiency and environmental sustainability (Vardhan et al., 2021).

The use of virtual reality (VR) and augmented reality (AR) in maritime training represents another significant advancement. These immersive technologies provide interactive experiences that enhance the understanding of complex navigational concepts, including the wheel over point. By combining theoretical knowledge with practical application, VR and AR tools bridge the gap between classroom learning and real-world operations (Shen et al., 2019).

2.2 Practical Applications and Case Studies

Practical applications of wheel over point concepts are critical for ensuring the safety and efficiency of maritime operations. Numerous case studies have documented the successful implementation of these principles in various maritime contexts, offering valuable lessons and best practices (Kamis & Ahmad Fuad, 2021).

One notable example is the application of wheel over point strategies in busy port areas. Ports such as Rotterdam and Singapore have implemented advanced navigation systems that utilize real-time data to optimize vessel maneuvering and reduce the risk of accidents. These systems continuously monitor vessel positions and environmental conditions, providing navigators with precise instructions on when to initiate turns (Filipiak et al., 2020).

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Research has also demonstrated the effectiveness of wheel over point optimization in reducing fuel consumption and emissions. By fine-tuning maneuvering strategies, vessels can maintain optimal speeds and trajectories, leading to significant environmental benefits. This approach aligns with global efforts to enhance the sustainability of maritime operations (De et al., 2019).

Moreover, the adoption of wheel over point principles in pilot training programs has yielded positive results. Pilots trained with a thorough understanding of these concepts are better equipped to handle challenging navigational scenarios, such as navigating through narrow channels and under adverse weather conditions. This training has been instrumental in improving overall navigational safety and efficiency (Mallam et al., 2019).

4.0 Challenges and Future Directions

Despite the advancements in understanding and applying wheel over points, several challenges remain. The complexity of accurately modeling hydrodynamic interactions and external forces poses ongoing difficulties for researchers and practitioners. Modelling hydrodynamic interactions requires intricate calculations to forecast the stresses and torques exerted on boats, which are influenced by several environmental parameters, such as ship draft and water depth (Kamis, Ahmad Fuad, Ashaari, Noor, et al., 2021; Zhang et al., 2021) as seen in Figure 2.

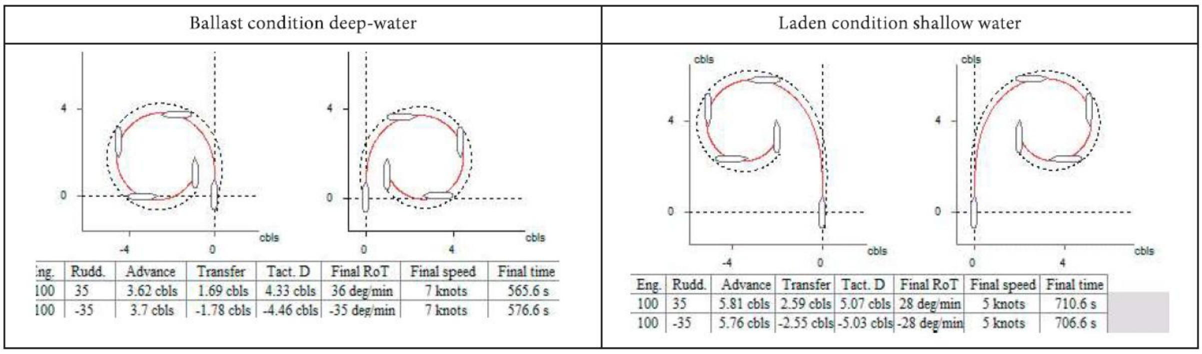

Figure 2: The variation in a ship's draft impacts the turning radius of the vessel (Kamis, Ahmad Fuad, Ashaari, Noor, et al., 2021).

One significant challenge is the variability of environmental conditions. Factors such as tidal currents, wind, and wave patterns can significantly impact the accuracy of wheel over point calculations. Developing robust models that can adapt to these changing conditions is essential for enhancing the reliability of navigational systems (Ley & Bruus, 2016).

Another challenge is the integration of emerging technologies into existing maritime infrastructures. While AI, VR, and AR offer substantial benefits, their implementation requires significant investments in training and equipment. Ensuring that these technologies are accessible and user-friendly is crucial for their widespread adoption (Vacondio et al., 2021).

Future research should focus on developing adaptive navigation systems that can respond dynamically to real-time data. The integration of IoT devices and advanced sensors can provide continuous monitoring and feedback, enabling vessels to adjust their maneuvering strategies on the fly (Zhang et al., 2021). Additionally, collaborative efforts between academia, industry, and regulatory bodies are essential for establishing standardized practices and guidelines for wheel over point determination (Vacondio et al., 2021).

5.0 Conclusion

The concept of the wheel over point is fundamental to the safe and efficient navigation of single propeller vessels. Through a combination of theoretical frameworks, technological advancements, and practical applications, significant progress has been made in optimizing these maneuvers. However, ongoing research and innovation are necessary to address the remaining challenges and further enhance navigational safety and operational efficiency.

REFERENCES

Chauvin, C., Lardjane, S., Morel, G., Clostermann, J. P., & Langard, B. (2013). Human and organisational factors in maritime accidents: Analysis of collisions at sea using the HFACS. *Accident Analysis and Prevention*, *59*. https://doi.org/10.1016/j.aap.2013.05.006

De, A., Choudhary, A., & Tiwari, M. K. (2019). Multiobjective Approach for Sustainable Ship Routing and Scheduling with Draft Restrictions. *IEEE Transactions on Engineering Management*, *66*(1). https://doi.org/10.1109/TEM.2017.2766443

Faltinsen, O. M. (2006). Hydrodynamic features of high-speed vessels. *Ships and Offshore Structures*, *1*(1). https://doi.org/10.1533/saos.2005.0010

Filipiak, D., Węcel, K., Stróżyna, M., Michalak, M., & Abramowicz, W. (2020). Extracting Maritime Traffic Networks from AIS Data Using Evolutionary Algorithm. *Business and Information Systems Engineering*, *62*(5). https://doi.org/10.1007/s12599-020-00661-0

Gunathilake, W. D. N. Y., Kodikara, N. D., Keppitiyagama, C. I., & Sandaruwan, K. D. (2014). A novel approach to automate surrounding ships in a virtual maritime environment. *2014 14th International Conference on Advances in ICT for Emerging Regions (ICTer)*, 78–84. https://doi.org/10.1109/ICTER.2014.7083883

IMO ISM. (2018). *International Safety Management Code (ISM Code)*. IMO Publishing.

ITTC. (2002). *Full Scale Measurements Manoeuvrability Full Scale Manoeuvring Trials Procedure*. ITTC - Recommended Procedure. https://www.ittc.info/media/8179/75-04-02-01.pdf

Kamis, A. S., & Ahmad Fuad, A. F. (2021). A Concept Explanation on the Development of Wheel Over Point Mathematical Model for Efficient Course Alteration. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, *15*(4), 795–798. https://doi.org/10.12716/1001.15.04.11

Kamis, A. S., Ahmad Fuad, A. F., Anwar, A. Q., & Ali, S. A. (2022). Assessing the Efficacy of the Advance Transfer Technique in Calculating the Wheel Over Point Through Simulation Studies. In *Advanced Structured Materials* (Vol. 166, pp. 129–144). https://doi.org/10.1007/978-3-030-89988-2_9

Kamis, A. S., Ahmad Fuad, A. F., Ashaari, A., & Mohd Noor, C. W. (2021). Wheel over point mathematical model. *Ocean Systems Engineering*, *11*(3), 203–216. https://doi.org/10.12989/ose.2021.11.3.203

Kamis, A. S., Ahmad Fuad, A. F., Ashaari, A., Noor, C. W. M., & Ali, S. A. (2021). Development of WOP Mathematical Model for Optimum Track-Keeping. A Ship Simulation Study Using VLCC, Focusing on Hard Over Rudder Turning Circle with Three Stages of Validation Analysis. *Polish Maritime Research*, *28*(3), 156–174. https://doi.org/10.2478/pomr-2021-0043

Komasawa, N., Berg, B. W., & Minami, T. (2019). Incorporating resilience competencies in simulation-based education to emergency response training. In *Journal of Clinical Anesthesia* (Vol. 53). https://doi.org/10.1016/j.jclinane.2018.09.032

Kuznetsov, V. I., Nikushchenko, D. V, Senkov, A. P., & Frumen, A. I. (2021). Provision of High Maneuverability and Navigation Safety on Ice-Class Vessels with Electric Propulsion Plants. *Russian Electrical Engineering*, *92*(5), 280–283. https://doi.org/10.3103/S1068371221050072

Lee, C. K. (2012). Numerical study of hydrodynamic interaction on a vessel in restricted waterways. *International Journal of Naval Architecture and Ocean Engineering*, *4*(1), 1–9. https://doi.org/10.2478/IJNAOE-2013-0073

Lee, C. K., Moon, S. B., Oh, J. S., & Lee, S. M. (2015). Numerical analysis for hydrodynamic interaction effects between vessel and semi-circle bank wall. *International Journal of Naval Architecture and Ocean Engineering*, *7*(4). https://doi.org/10.1515/ijnaoe-2015-0048

Ley, M. W. H., & Bruus, H. (2016). Continuum modeling of hydrodynamic particle-particle interactions in microfluidic high-concentration suspensions. *Lab on a Chip*, *16*(7). https://doi.org/10.1039/c6lc00150e

Liu, J., & Hekkenberg, R. (2017). Sixty years of research on ship rudders: effects of design choices on rudder performance. *Ships and Offshore Structures*, *12*(4), 495–512. https://doi.org/10.1080/17445302.2016.1178205

Liu, Y., Xue, J., Yang, B., Zhu, M., Guo, W., Pan, F., Ye, C., Wang, W., Liang, T., Li, X., & Zhang, L. (2021). The acoustic system of the fendouzhe hov. *Sensors*, *21*(22). https://doi.org/10.3390/s21227478

Mallam, S. C., Nazir, S., & Renganayagalu, S. K. (2019). Rethinking maritime education, training, and operations in the digital era: Applications for emerging immersive technologies. In *Journal of Marine Science and Engineering* (Vol. 7, Issue 12). https://doi.org/10.3390/JMSE7120428

Miyazaki, H., Nonaka, K., Nimura, T., & Ueno, M. (2001). Study of Interaction between Ship Hull and Rudder by Computation. *Journal of the Society of Naval Architects of Japan*, *2001*(189). https://doi.org/10.2534/jjasnaoe1968.2001.63

Muscari, R., Dubbioso, G., Viviani, M., & Di Mascio, A. (2017). Analysis of the asymmetric behavior of propeller–rudder system of twin screw ships by CFD. *Ocean Engineering*, *143*. https://doi.org/10.1016/j.oceaneng.2017.07.056

Nicolescu, M., Leigh, R., Olenderski, A., Louis, S., Dascalu, S., Miles, C., Quiroz, J., & Aleson, R. (2007). A training simulation system with realistic autonomous ship control. *Computational Intelligence*, *23*(4). https://doi.org/10.1111/j.1467-8640.2007.00318.x

Omelchenko, T. Y., & Petrichenko, E. A. (2020). CONFIDERATION OF NAVIGATION DANGER AT THE CHOICE OF MANOEUVRE OF DIVERGENCE OF SHIP WITH TWO TARGETS. *Shipping & Navigation*, *30*(1), 99–106. https://doi.org/10.31653/2306-5761.30.2020.99-106

Razaghian, A. H., Ebrahimi, A., Zahedi, F., Javanmardi, M. R., & Seif, M. S. (2021). Investigating the effect of geometric parameters on hydrodynamic and hydro-acoustic performances of submerged propellers. *Applied Ocean Research*, *114*. https://doi.org/10.1016/j.apor.2021.102773

Roshan, F., dashtimanesh, A., Tavakoli, S., Niazmand, R., & Abyn, H. (2020). Hull–propeller interaction for planing boats: a numerical study. *Ships and Offshore Structures*. https://doi.org/10.1080/17445302.2020.1790295

Sahin, B. (2016). The Obligations of Single-Propeller Vessels at the Head-On Situation. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, *10*(1). https://doi.org/10.12716/1001.10.01.11

Shen, H., Zhang, J., Yang, B., & Jia, B. (2019). Development of an educational virtual reality training system for marine engineers. *Computer Applications in Engineering Education*, *27*(3). https://doi.org/10.1002/cae.22099

Vacondio, R., Altomare, C., De Leffe, M., Hu, X., Le Touzé, D., Lind, S., Marongiu, J. C., Marrone, S., Rogers, B. D., & Souto-Iglesias, A. (2021). Grand challenges for Smoothed Particle Hydrodynamics numerical schemes. In *Computational Particle Mechanics* (Vol. 8, Issue 3). https://doi.org/10.1007/s40571-020-00354-1

Vardhan, H., Volgyesi, P., & Sztipanovits, J. (2021). Machine learning assisted propeller design. *ICCPS 2021 - Proceedings of the 2021 ACM/IEEE 12th International Conference on Cyber-Physical Systems (with CPS-IoT Week 2021)*. https://doi.org/10.1145/3450267.3452001

Villa, D., Franceschi, A., & Viviani, M. (2020). Numerical analysis of the rudder-propeller interaction. *Journal of Marine Science and Engineering*, *8*(12). https://doi.org/10.3390/jmse8120990

Wang, Y., Chai, S., & Nguyen, H. D. (2020). Experimental and numerical study of autopilot using Extended Kalman Filter trained neural networks for surface vessels. *International Journal of Naval Architecture and Ocean Engineering*, *12*, 314–324. https://doi.org/10.1016/j.ijnaoe.2019.11.004

Yaacob, A., Rashidi, M., & Koto, J. (2014). Marine Navigation Collision Preventing System. *Jurnal Teknologi*, *69*(7), 97–100. https://doi.org/10.11113/jt.v69.3271

Zhang, G., Hu, T., Sun, Z., Wang, S., Shi, S., & Zhang, Z. (2021). A δSPH–SPIM coupled method for fluid–structure interaction problems. *Journal of Fluids and Structures*, *101*. https://doi.org/10.1016/j.jfluidstructs.2020.103210

Zhu, F. X., Miao, L. M., & Liu, W. (2014). Research on vessel trajectory multi-dimensional compression algorithm based on Douglas-Peucker theory. *Applied Mechanics and Materials*, *694*. https://doi.org/10.4028/www.scientific.net/AMM.694.59