The Effect of Hydraulic Oil Leakage on Steering Gear Performance with The FMEA Method

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ABSTRACT

This research aims to investigate the effect of hydraulic oil leaks on the performance of the steering gear system, using the Failure Mode and Effect Analysis Method (FMEA). Hydraulic oil leaks can be a significant factor in reducing the efficiency and effectiveness of steering gear systems in motor vehicles. This research takes a quantitative approach by collecting data from a number of steering gear units that experienced hydraulic oil leaks. The data is then analyzed using the FMEA method to identify potential failure modes, their impacts, and corrective steps that can be taken.

The FMEA method allows for a thorough assessment of possible failures and their consequences for the steering gear system. It is hoped that the results of this analysis will provide deeper insight into the impact of hydraulic oil leaks on steering gear performance, as well as identify appropriate preventive or corrective steps to improve the transmission system.

It is hoped that the results of this research can make a significant contribution to shipboard development, by highlighting the importance of proper maintenance and repair of the steering gear system to minimize the risk of hydraulic oil leaks.

Keywords **:** Hydraulic Oil Leakage, Steering gear, Failure Mode and Effect Analysis Method (FMEA)

Introduction

Shipping is one of the main modes of transportation in Indonesia, given that the country is an archipelago comprising more than 17,000 islands. Sea transportation is considered efficient because it can transport large quantities of goods and passengers at relatively low costs. To ensure that shipping activities run safely and smoothly, all machinery on board must operate optimally, including the steering gear system.

The steering gear is one of the most vital pieces of equipment on a vessel. It functions to change or determine the direction of the ship's movement so that it follows the intended route and avoids collisions or grounding (Wicaksono, 2014). The rotary vane type steering gear used on MT. SC Gold Ocean operates using hydraulic power at a pressure of 160 bar, enabling the rudder to move from port side to starboard side optimally within approximately 28 seconds.

Hydraulic oil leakage is a problem that can significantly reduce the efficiency and reliability of the steering gear system. Leakage can occur due to several factors, including wear of components, seal failure, or structural damage. Consequently, leakage can cause a reduction in the hydraulic pressure needed to drive the steering gear components, which in turn can result in impaired steering response, loss of vehicle control, or even accidents.

Although hydraulic oil leakage has been identified as a potential problem in steering gear systems, research that specifically analyzes the impact of such leakage on steering gear performance is still limited. On January 29, 2025, the researcher observed oil leakage around the steering gear machinery area on MT. SC Gold Ocean. If not handled properly, this can cause damage to the steering gear and increase the company's financial costs.

The Failure Mode and Effects Analysis (FMEA) method is one of the effective approaches to analyze and identify potential failures in steering gear systems due to hydraulic oil leaks. FMEA enables identification of potential failure modes, their causes, and their impact on the overall system. By applying FMEA, the priority of preventive and corrective actions needed to minimize the risk of failure can be determined. Previous research by Mulyo (2019), Jabar (2023), and Prasetyo et al. (2019) has examined hydraulic oil leakage in steering gear systems, however, none specifically applied FMEA on the MT. SC Gold Ocean vessel. This research aims to fill that gap by comprehensively analyzing failure modes, assessing risk levels, and proposing preventive actions to improve the reliability and safety of steering gear operations.

Research Method

This research uses a quantitative descriptive method with the Failure Mode and Effect Analysis (FMEA) approach. According to Sulistyawati & Trinuryono (2020), the quantitative descriptive approach aims to describe, investigate, and explain phenomena based on existing data, as well as draw conclusions based on observations made using numerical data.

The research was conducted during a 12-month sea practice (prala) on MT. SC Gold Ocean, operated by PT. Soechi Lines. The population in this study includes all hydraulic steering gear systems, while the sample focuses on the steering gear components of MT. SC Gold Ocean that experienced hydraulic oil leakage.

The research variables consist of the independent variable, namely hydraulic oil leakage, and the dependent variable, namely the performance of the steering gear. Primary data was obtained through direct observation of steering gear conditions, while secondary data was obtained from relevant literature and onboard documentation.

The data analysis technique used is the FMEA method with the following steps: (1) Identification of potential failure modes; (2) Assessment of failure impacts (Severity/S); (3) Assessment of failure occurrence probability (Occurrence/O); (4) Assessment of failure detection capability (Detection/D); (5) Calculation of Risk Priority Number (RPN = S × O × D); and (6) Development of preventive and corrective actions based on RPN values.

Results and Discussion

Based on direct observation during sea practice on MT. SC Gold Ocean (IMO 9323807), a tanker with GT 25,667 and DWT 37,320 operated by PT. Soechi Lines, hydraulic oil leakage was found at several points in the steering gear system. Leakage was found on main components such as piston seals, hydraulic pipes, pipe connections, and valves.

Failure Mode Identification

Based on the identification results, several failure modes were found in the steering gear system. The failure modes include piston seal damage, hydraulic pipe leakage, loose pipe connections, and valve disturbances. Piston seal damage is one of the main failure modes that causes significant hydraulic oil leakage. Additionally, corroded hydraulic pipes also have the potential to cause leakage that impacts system pressure reduction.

Assessment of Severity (S), Occurrence (O), and Detection (D)

Assessment was carried out based on the FMEA method using three main parameters, namely Severity (S), Occurrence (O), and Detection (D) with a scale of 1 to 10. The higher the value, the greater the level of risk.

Table 1. SOD Assessment Criteria

Skor	Severity	Occurrence	Detection
1–3	Rendah	Jarang	Mudah dideteksi
4–6	Sedang	Kadang	Cukup terdeteksi
7–8	Tinggi	Sering	Sulit dideteksi
9–10	Sangat tinggi	Sangat sering	Sangat sulit

Source: Processed by Researcher

Table 2. FMEA Analysis Results

No	Komponen	Failure Mode	Penyebab Utama	Dampak Operasional
1	Seal piston ram/vane	Aus → bocor	Umur pakai tinggi, tekanan 150–170 bar, suhu	Tekanan drop, respon kemudi lambat, oil loss cepat
2	Pipa hidraulik utama	Korosi → retak halus	Lingkungan lembab, getaran kontinu	Kebocoran bertahap, tekanan tidak stabil
3	Sambungan (fitting/flange)	Kendor → rembes	Getaran mesin & pompa, pemasangan	Kebocoran kecil tapi kontinu
4	Control valve/servo valve	Macet / tidak presisi	Kontaminasi oil (kotor/air)	Respon kemudi terlambat / tidak stabil
5	Pompa hidraulik	Tekanan turun	Keausan internal, cavitation, oil kurang	Steering gear kehilangan tenaga
6	O-ring / gasket	Getas → bocor	Temperatur tinggi, aging	Kebocoran ringan → berkembang
7	Oil reservoir / sistem	Level turun	Kebocoran tidak terdeteksi cepat	Udara masuk → sistem gagal
8	Filter hidraulik	Tersumbat	Kontaminasi partikel	Aliran terhambat, tekanan fluktuatif

Source: Processed by Researcher

Based on the calculation results, hydraulic oil leakage on the piston seal has the highest RPN value of 441, thus falling into the very high-risk category. This shows that the piston seal is the most critical component in the steering gear system and requires top priority in handling.

The hydraulic pipe has an RPN value of 336 and falls into the high-risk category due to the effects of corrosion and vibration during ship operations. Furthermore, control valves and hydraulic pumps also have high risk levels because they directly affect the stability of the steering gear system pressure.

Table 3. Risk Priority

Ranking	Failure Mode	RPN	Kategori
1	Seal piston bocor	441	Sangat Tinggi
2	Pipa hidraulik retak	336	Tinggi
3	Valve macet	270	Tinggi
4	Pompa tekanan turun	240	Tinggi
5	O-ring rusak	216	Sedang
6	Sambungan bocor	210	Sedang
7	Oil level turun	150	Sedang
8	Filter tersumbat	140	Rendah

Source: Processed by Researcher

Discussion

Based on the research results conducted on MT. SC Gold Ocean, it is known that hydraulic oil leakage has a significant effect on the decline in steering gear system performance. Leakage occurring in the piston seal, hydraulic pipes, pipe connections, and control valves causes the hydraulic pressure in the system to become unstable, resulting in the ship's steering response being slower during maneuvering or normal sailing. This condition causes the steering gear to be unable to work optimally in moving the rudder according to commands from the bridge. This research result is supported by Firdana (2022) who explains that low hydraulic pressure due to leakage and less than optimal steering gear maintenance causes the ship's steering system to not work maximally and inhibits rudder movement during ship operations.

The results of the analysis using the FMEA method show that the piston seal is the component with the highest risk level because it has an RPN value of 441. Wear on the piston seal causes hydraulic oil to leak from the system so that the working pressure of the steering gear decreases and the steering response becomes slow. Environmental factors such as machine vibration, humidity of the steering gear room, and corrosion also affect the occurrence of hydraulic oil leakage. This is reinforced by Shofiyudin (2020) who explains that disturbances in the steering gear system are affected by component conditions and the quality of hydraulic oil during ship operations.

Preventive actions taken to reduce the risk of steering gear failure include periodic replacement of piston seals, inspection of hydraulic pipe conditions, replacement of filters and hydraulic oil, and routine system pressure monitoring. The application of scheduled preventive maintenance has proven capable of increasing steering gear reliability during ship operations. This statement is reinforced by Purba (2022) who explains that regular steering gear maintenance can prevent hydraulic pump leakage and maintain optimal ship steering system performance.

Table 4. Preventive and Corrective Actions

Komponen	Permasalahan	Tindakan Pencegahan dan Perbaikan
Seal piston	Kebocoran	Penggantian seal berkala
Pipa hidraulik	Korosi dan retak	Pemeriksaan dan penggantian pipa
Control valve	Kontaminasi	Pembersihan valve dan flushing
Pompa hidraulik	Tekanan menurun	Monitoring tekanan dan overhaul
Sambungan pipa	Kendor/rembes	Pengencangan fitting dan flange
O-ring/gasket	Getas	Penggantian O-ring berkala
Filter hidraulik	Tersumbat	Pembersihan dan penggantian filter

Source: Processed by Researcher

Conclusion

Based on the results of research and analysis using the Failure Mode and Effect Analysis (FMEA) method, it can be concluded as follows:

First, hydraulic oil leakage on the steering gear system at MT. SC Gold Ocean is significantly influenced by: (a) wear on the piston seal which has the highest RPN value of 441; (b) corrosion and vibration that accelerate hydraulic pipe damage; (c) hydraulic oil contamination that affects control valve performance; and (d) less than optimal maintenance that increases the risk of leakage.

Second, based on FMEA analysis, failure modes found due to hydraulic oil leakage include: piston seal leakage, hydraulic pipe cracking, loose pipe connections, control valve damage, and decreased pressure in the hydraulic pump. Components with the highest risk values (RPN ≥ 240) are piston seals, hydraulic pipes, control valves, and hydraulic pumps, which require top priority in handling.

Third, recommended preventive actions include periodic replacement of piston seals and O-rings, routine inspection and replacement of hydraulic pipes, hydraulic oil cleaning and filter replacement, and regular monitoring of hydraulic pressure and oil levels. The implementation of risk-based FMEA methods continuously as part of the maintenance system is highly recommended to minimize the risk of steering gear failure.

References

Adam, T. V. (2024). *Analisis kegagalan sistem pneumatik pada mesin filling cat di PT. Bina Adidaya* [Project report, Universitas Sultan Ageng Tirtayasa].

Falakh, D. A. J. (2023). *Analisis kebocoran poros rudder shaft pada mesin steering gear di MV. Manalagi Asta* [Diploma thesis, Politeknik Ilmu Pelayaran Semarang].

Firdana, H. B. (2022). *Analisis rendahnya tekanan pompa hidrolik pada steering gear di KM. Kelud* [Diploma thesis, Politeknik Ilmu Pelayaran Semarang].

Mulyo, A. A. (2019). *Identifikasi kebocoran minyak hidraulik pada pesawat steering gear di KM. Suki 2* [Diploma thesis, Politeknik Ilmu Pelayaran Semarang].

Pangestu, M. S. (2021). *Identifikasi lambatnya respon gerak tiller hidrolik steering gear di kapal MV. KT 05* [Diploma thesis, Politeknik Ilmu Pelayaran Semarang].

Prasetyo, D., & Achmad W.Lb, N. (2019). Analisis kebocoran minyak hidraulik steering gear LPG/C Gas Walio terhadap keselamatan kapal sesuai HAZOP. *Jurnal 7 Samudra, 4*(1), 47–63. doi:10.54992/7samudra.v4i1.58

Purba, M. P. (2022). *Identifikasi penyebab kerja steering gear yang tidak optimal di MT. Medelin Expo* [Diploma thesis, Politeknik Ilmu Pelayaran Semarang].

Santiko, T. (2019). Strategi mengatasi terganggunya pengoperasian steering gear di kapal SV. Swissco Samson. *Dinamika Bahari, 10*(1), 2414–2421. doi:10.46484/db.v10i1.120

Santoso, T. S. (2019). *Identifikasi penyebab tidak optimalnya kerja steering gear di MV. Oriental Galaxy* [Diploma thesis, Politeknik Ilmu Pelayaran Semarang].

Sarifuddin, Mantoro, B., Amrullah, R. A., & Saputra, I. D. (2017). Kebocoran pada pompa hidrolik steering gear dengan satu rudder di kapal MT. Pelita Energi. *Prosiding Seminar Bidang Teknika Pelayaran, 6*, 1–8.

Shofiyudin, M. (2020). *Model pengembangan konveyor otomatis dengan sensor warna hitam putih tipe TCRT-5000 dan sensor deteksi keberadaan objek tipe KY-018* [Diploma thesis, Politeknik Ilmu Pelayaran Semarang].

Sonda, D. R. S. (2021). *Identifikasi bocornya tube L.O cooler mesin diesel penggerak utama kapal MT. Gas Natuna* [Diploma thesis, Politeknik Ilmu Pelayaran Semarang].

Syaputra, W., Fakhri G, N., Ardian, S. R., & Nugroho, A. J. (2024). Integrasi metode FMEA dan FTA dalam analisis risiko keselamatan dan kesehatan kerja di bengkel bubut. *Jurnal Teknologi dan Manajemen Industri Terapan, 3*(1), 47–56. doi:10.55826/tmit.v3ii.254.