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Analysis of Factors Causing Difficult Initial Starting of the Main Engine on the AHTS SK Canopus

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ABSTRACT

Difficulty in starting a ship's main engine can delay departures, disrupt operations, and create safety risks. This study analyses the factors that caused the initial starting difficulty of the starboard main engine on the AHTS SK Canopus, the impacts of the failure, and the corrective measures applied. A descriptive qualitative design was used, based on direct observation and documentation on board over a 12-month period; the battery data were processed with SPSS (paired samples statistics, paired samples correlations, and the Wilcoxon signed-rank test) and checked with basic electrical formulas. On 25 July 2023, the starboard main engine failed to start during manoeuvring because the battery voltage was below the specification in the manual book, as the battery had exceeded its service life. Compared with the normal condition, the abnormal battery required 13.3 hours to charge instead of 6.6 hours and drew a charging load of 6.43 A instead of 3.18 A, while the overheated battery showed a load of 4.83 A. After the battery was replaced according to the manufacturer's specification, the charging time fell to 3.3 hours and the charging load to 1.6 A, and the statistical indicators returned to those of the normal condition. The study concludes that battery condition is a key factor in the starting reliability of the main engine and recommends periodic monitoring of battery voltage and charging time within the planned maintenance system to prevent similar failures.

Keywords: Main Engine, Initial Start, Battery, Voltage, Routine Maintenance

ABSTRAK

Kesulitan start awal pada mesin induk kapal dapat menyebabkan keterlambatan keberangkatan, gangguan operasional, dan risiko keselamatan. Penelitian ini bertujuan untuk menganalisis faktor-faktor penyebab sulitnya start awal pada mesin induk sebelah kanan kapal AHTS SK Canopus, dampak yang ditimbulkan, serta langkah perbaikan yang diterapkan. Penelitian menggunakan pendekatan deskriptif kualitatif melalui observasi langsung dan dokumentasi di atas kapal selama 12 bulan; data kondisi baterai diolah dengan SPSS (paired samples statistics, paired samples correlations, dan uji Wilcoxon signed-rank) serta diperiksa dengan rumus kelistrikan dasar. Pada tanggal 25 Juli 2023, mesin induk sebelah kanan tidak dapat di-start saat olah gerak karena voltase baterai berada di bawah spesifikasi buku manual akibat usia baterai yang telah melampaui masa pakainya. Dibandingkan kondisi normal, baterai abnormal membutuhkan waktu pengisian 13,3 jam (normal 6,6 jam) dengan beban isi 6,43 A (normal 3,18 A), sedangkan baterai yang panas menunjukkan beban isi 4,83 A. Setelah baterai diganti sesuai spesifikasi pabrikan, waktu pengisian turun menjadi 3,3 jam dan beban isi menjadi 1,6 A, serta indikator statistik kembali sama dengan kondisi normal. Penelitian ini menyimpulkan bahwa kondisi baterai merupakan faktor kunci keandalan start mesin induk dan merekomendasikan pemantauan voltase serta waktu pengisian baterai secara berkala dalam sistem perawatan terencana untuk mencegah kegagalan serupa.

Kata kunci: Mesin Induk, Start Awal, Baterai, Voltase, Perawatan Rutin

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1. INTRODUCTION

Difficulty in starting the main engine is a common problem on board ships. This condition can delay departures, disrupt operations, and even create hazards if it is not handled promptly. Field observations indicate that one of the main reasons an engine fails to start is a battery that does not meet the technical specification in terms of voltage or capacity. Apart from technical factors, failures of ship propulsion engines can also be triggered by human factors in operation and maintenance (Abrori et al., 2023).

According to Sutrisno and Purnomo (2022), the engine support systems, particularly the fuel system and the starting system, play an important role in maintaining diesel engine performance. Routine maintenance and inspection of components such as batteries are therefore crucial to ensure the operational readiness of the ship.

1.1. Diesel Engines as Ship Main Engines

A diesel engine is an internal combustion engine that operates on the principle of high compression, with ignition caused by the high temperature of the compressed air. Diesel engines are commonly used as ship main engines because of their high thermal efficiency, high torque at low speed, and long-term durability; consequently, condition monitoring and fault diagnosis of these engines are major concerns in ship operation (Knežević et al., 2020; Koçak et al., 2023).

According to Sutrisno and Purnomo (2022), diesel engine performance is strongly influenced by support systems such as the fuel, lubrication, cooling, and

starting systems, while engine performance can be evaluated through measured testing (Wahyu, 2019). Previous studies on main engine maintenance in Indonesia have mostly focused on the fuel system, such as injectors (Achmat et al., 2024), the starting air system and its compressor (Rachman et al., 2020; Nawawi et al., 2021), and starter motor performance (Pakaya et al., 2023). Studies on initial starting failures of ship main engines caused by battery condition remain limited.

1.2. Diesel Engine Starting Systems

The starting system of a diesel engine rotates the crankshaft at the beginning of ignition so that the engine can begin its working cycle. On ship main engines, the starting system generally uses high-pressure air or an electrical system that relies on batteries (Nawawi et al., 2021; Pakaya et al., 2023). If the starting system does not work properly, the engine cannot start (start failure), which may disrupt ship operations. In starting air systems, component defects such as faulty starting air valves can even cause explosions in the starting air manifold (Chybowski et al., 2022).

1.3. Role of the Battery in the Starting System

The battery is an essential component of the diesel engine starting system, especially for electric starters. It supplies electric current to the starter motor so that the motor can turn the crankshaft. The battery capacity and voltage must match the engine specification to deliver sufficient initial power, and a decline in the battery state of health reduces this capability (Jiang & Song, 2021; Sadabadi et al., 2021). The cranking capability of lead-acid batteries also drops sharply under non-ideal operating conditions, such as low temperatures (Bauknecht et al., 2023).

Lead-acid batteries age through mechanisms such as sulphation, grid corrosion, and electrolyte loss, which are accelerated by poor maintenance and high operating temperatures (Ruetschi, 2004; Prasad et al., 2023). An analysis of field-aged starter batteries showed that capacity loss is the main cause of starting failure (Conradt et al., 2023), and such defects can be recognised from changes in voltage and current during charging and loading (Puzakov & Smirnov, 2020; Kędzior et al., 2023). Periodic inspection and replacement of batteries are therefore important procedures in ship maintenance.

1.4. Maintenance and Prevention of Operational Disruptions

Preventive maintenance and periodic inspection of the starting system, particularly the battery, are essential to prevent operational disruptions on board. Good maintenance strategies, both preventive and predictive, can extend component service life and improve the reliability of ship machinery under various operating conditions (Jimenez et al., 2020; Song et al., 2022; Karatuğ et al., 2023). For starter batteries, failure indication and battery condition monitoring systems have been shown to help prevent starting failures of emergency generator sets (D'Orazio et al., 2020).

Based on this background and review, this study analyses the factors that cause difficulty in the initial start of the main engine, focusing on the effect of battery condition on engine performance. It also aims to identify the resulting impacts and the solutions that can be applied to prevent similar problems in the future.

2. METHOD

This study used a descriptive qualitative approach supported by simple quantitative analysis. It aimed to describe systematically and factually the conditions and factors that cause difficulty in the initial start of a ship's main engine, focusing on the starting system components, particularly the performance of the main engine battery. The study was conducted directly on board the AHTS SK Canopus over a 12-month period. Data were collected through direct observation and documentation of the condition of the main engine battery.

Battery charging parameters were observed under four conditions, namely normal, abnormal, alarm 1, and after repair, with six measurements for each condition (N = 6). The data were processed in SPSS using paired samples statistics, paired samples correlations, and the Wilcoxon signed-rank test, and were then checked with basic electrical formulas (Ohm's law, current, and self-discharge). Validity and reliability tests were also performed on the research variables (X1–X4 and Y). The results were interpreted to trace the root cause of the problem and to map the repair method and maintenance steps, in line with failure diagnosis approaches for marine diesel engine systems (Knežević et al., 2020).

3. RESULTS AND DISCUSSION

3.1. Results

This section presents the results on the factors that caused difficulty in the initial start of the main engine of the AHTS SK Canopus. Observation and data collection were carried out through direct observation and documentation on board. The collected data were then processed and analysed to identify the root cause of the problem and its effect on ship operations.

On 25 July 2023, when the AHTS SK Canopus was about to manoeuvre into port, the starboard main engine could not be started. Inspection revealed that the battery voltage was insufficient because the battery had exceeded its service life. The observed battery conditions at each stage are presented in Table 1 and Figure 1.

Table 1. Observed Condition of the Main Engine Battery

Battery (condition)	Nominal battery voltage (V)	Charging current (A)	Charging time (h)	Physical condition	Minimum voltage (V)	Maximum voltage (V)	Charging load (A)
Battery 1 (normal)	12	50	6.6	Normal	10.5	12.6	3.18
Battery 2 (abnormal)	12	50	13.3	Odour	10.5	12.6	6.43
Battery 3 (alarm 1)	12	50	10.0	Hot, odour	10.5	12.6	4.83
Battery 4 (after repair)	12	50	3.3	Normal	10.5	12.6	1.60

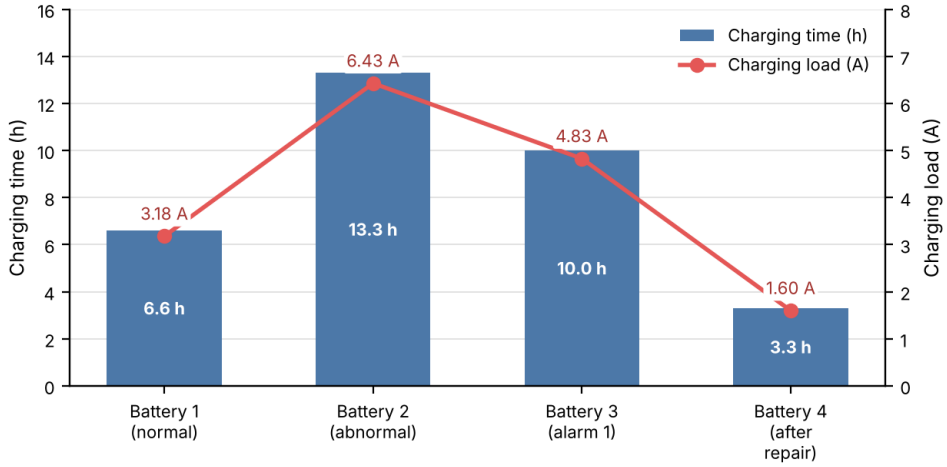


Figure 1. Charging Time and Charging Load of the Battery under Each Observed Condition

Figure 1 shows that the charging time and charging load increased sharply in the abnormal condition (13.3 h; 6.43 A) and the alarm 1 condition (10.0 h; 4.83 A)

compared with the normal condition (6.6 h; 3.18 A), and then decreased after the battery was replaced (3.3 h; 1.60 A). The nominal battery voltage (12 V) and the charging current (50 A) were the same in all conditions, so these differences reflect the deterioration of the battery itself. The abnormal batteries also showed physical symptoms in the form of odour and heat.

3.2. Data Analysis

3.2.1. SPSS Analysis

The results of the paired samples statistics for the battery condition data are presented in Table 2.

Table 2. Paired Samples Statistics

Pair	Condition	Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Battery 1 normal	25.7133	6	25.73740	10.50725
	Battery 2 abnormal	16.6550	6	16.56505	6.76265
Pair 2	Battery 1 normal	25.7133	6	25.73740	10.50725
	Battery 3 abnormal	37.4217	6	49.47943	20.19989
Pair 3	Battery 1 normal	25.7133	6	25.73740	10.50725
	Battery 4 normal	25.7133	6	25.73740	10.50725
Pair 4	Battery 2 abnormal	16.6550	6	16.56505	6.76265
	Battery 3 abnormal	37.4217	6	49.47943	20.19989
Pair 5	Battery 2 abnormal	16.6550	6	16.56505	6.76265
	Battery 4 normal	25.7133	6	25.73740	10.50725
Pair 6	Battery 3 abnormal	37.4217	6	49.47943	20.19989
	Battery 1 normal	25.7133	6	25.73740	10.50725
Pair 7	Battery 3 abnormal	37.4217	6	49.47943	20.19989
	Battery 4 normal	25.7133	6	25.73740	10.50725
Pair 8	Battery 4 normal	25.7133	6	25.73740	10.50725
	Battery 2 abnormal	16.6550	6	16.56505	6.76265

Table 2 shows that the statistics of the battery in the abnormal conditions differ from those in the normal condition. Battery 3 (alarm 1) had the highest mean and standard deviation (37.4217 and 49.47943), whereas battery 2 (abnormal) had a lower mean (16.6550) than the normal condition (25.7133). After repair, the mean, standard deviation, and standard error of the mean of battery 4 were identical to those of the normal condition, indicating that the battery had returned to normal.

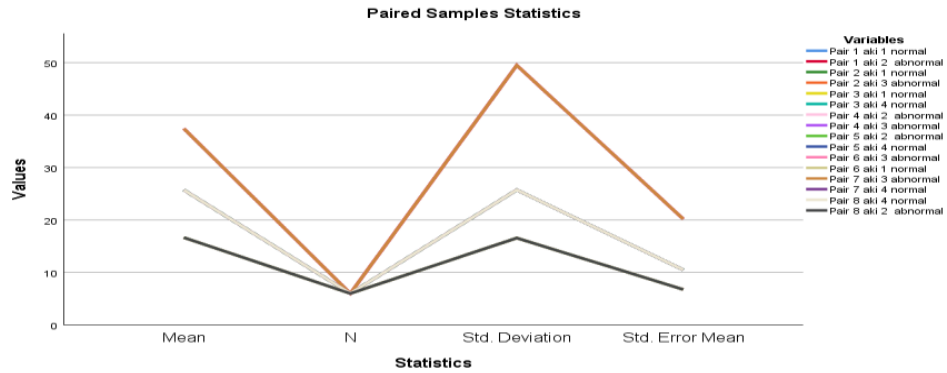


Figure 2. Paired Samples Statistics Chart

Figure 2 visualises the mean, number of samples, standard deviation, and standard error of the mean for each battery condition.

Table 3. Paired Samples Correlations

Pair	Variables	N	Correlation	Sig.
Pair 1	Battery 1 normal & battery 2 abnormal	6	0.478	0.338
Pair 2	Battery 1 normal & battery 3 abnormal	6	0.933	0.007
Pair 4	Battery 2 abnormal & battery 3 abnormal	6	0.130	0.805
Pair 5	Battery 2 abnormal & battery 4 normal	6	0.478	0.338
Pair 6	Battery 3 abnormal & battery 1 normal	6	0.933	0.007
Pair 7	Battery 3 abnormal & battery 4 normal	6	0.933	0.007
Pair 8	Battery 4 normal & battery 2 abnormal	6	0.478	0.338

Table 3 shows that the correlation between battery 1 (normal) and battery 3 (abnormal), 0.933, is very strong and significant (p = 0.007), whereas the correlation between the normal condition and battery 2 (abnormal), 0.478, is not significant (p = 0.338). Pair 3 (battery 1 normal and battery 4 after repair) yielded no correlation value because the data for the two conditions were identical, meaning that the battery condition after repair was the same as the normal condition. Because each condition comprised only six measurements, these correlations should be interpreted with caution.

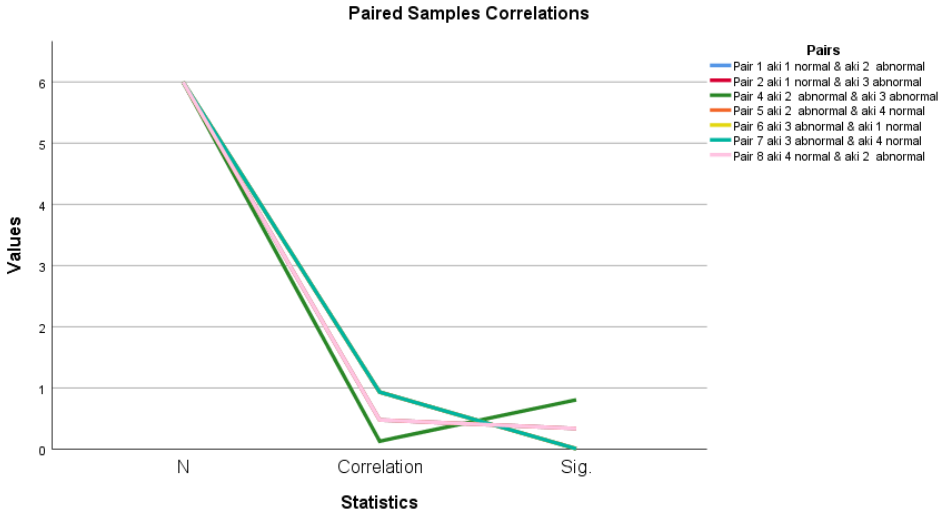


Figure 3. Paired Samples Correlations Chart

Figure 3 compares the variable pairs in terms of the number of samples, correlation, and significance. Although the number of samples in each pair is the same, the correlation and significance values vary among the normal–abnormal pairs. The results of the Wilcoxon signed-rank test comparing the normal and abnormal conditions are presented in Table 4.

Table 4. Ranks (Wilcoxon Signed-Rank Test)

Pair	Ranks	N	Mean Rank	Sum of Ranks
Battery 2 abnormal – battery 1 normal	Negative Ranks	1	2.00	2.00
	Positive Ranks	1	1.00	1.00
	Ties	4		
	Total	6		
Battery 3 abnormal – battery 1 normal	Negative Ranks	0	0.00	0.00
	Positive Ranks	2	1.50	3.00
	Ties	4		
	Total	6		
Battery 4 normal – battery 1 normal	Negative Ranks	0	0.00	0.00
	Positive Ranks	0	0.00	0.00
	Ties	6		
	Total	6		
Battery 3 abnormal – battery 2 abnormal	Negative Ranks	0	0.00	0.00
	Positive Ranks	2	1.50	3.00
	Ties	4		
	Total	6		
Battery 4 normal – battery 2 abnormal	Negative Ranks	1	1.00	1.00
	Positive Ranks	1	2.00	2.00
	Ties	4		
	Total	6		
Battery 1 normal – battery 3 abnormal	Negative Ranks	2	1.50	3.00
	Positive Ranks	0	0.00	0.00
	Ties	4		
	Total	6		
	Negative Ranks	2	1.50	3.00

Pair	Ranks	N	Mean Rank	Sum of Ranks
Battery 4 normal – battery 3 abnormal	Positive Ranks	0	0.00	0.00
	Ties	4		
	Total	6		
Battery 2 abnormal – battery 4 normal	Negative Ranks	1	2.00	2.00
	Positive Ranks	1	1.00	1.00
	Ties	4		
	Total	6		

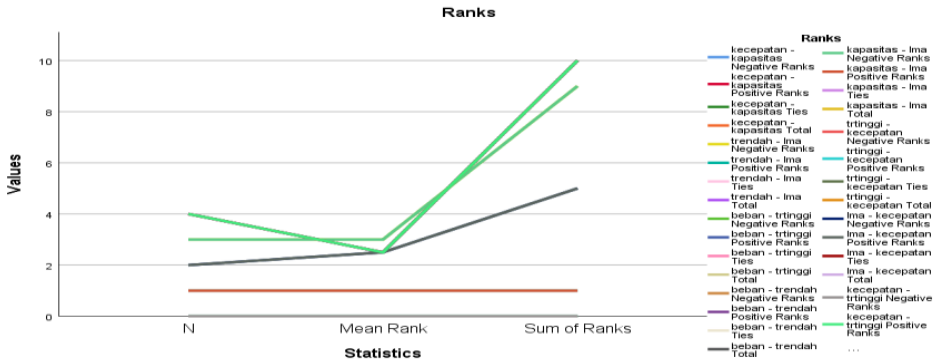


Figure 4. Ranks Chart

Table 4 and Figure 4 show that every pair comparing a normal condition with an abnormal condition contains rank changes (negative or positive ranks), whereas the pair of battery 1 (normal) and battery 4 (after repair) consists entirely of ties (6 of 6). This means that there is no difference between the battery condition after repair and the normal condition. Most of the other pairs are also dominated by ties (4 of 6), so the differences between conditions occurred in only some of the observed parameters.

3.2.2. Data Verification with Formulas

Verification with basic electrical formulas used a nominal battery voltage of 12 V, a charging current of 50 A, and a battery capacity of 200 Ah.

a. Equivalent resistance of the charging circuit. The resistance is calculated with Ohm's law in Equation (1).

$$R = \frac{V}{I} \tag{1}$$

where R is the resistance (Ω), V is the voltage (V), and I is the current (A). With V = 12 V and I = 50 A, R = 12/50 = 0.24 Ω. This value is the equivalent resistance at a charging current of 50 A, not the internal resistance of the battery.

b. Battery voltage. As a back-check, the voltage is calculated with Equation (2).

$$V = I \times R \tag{2}$$

With R = 0.24 Ω and I = 50 A, V = 50 × 0.24 = 12 V, which agrees with the nominal battery voltage.

c. Charging current. The current is calculated with Equation (3).

$$I = \frac{Q}{t} \tag{3}$$

where I is the current (A), Q is the electric charge (Ah), and t is the time (h). With Q = 200 Ah and t = 62.72 h, I = 200/62.72 = 3.19 A. This value is close to the charging load of the battery in the normal condition (3.18 A) in Table 1.

d. Charge lost through self-discharge. The lost charge is calculated with Equation (4).

$$Q_{\text{loss}} = C \times \frac{\text{self-discharge rate}}{100} \tag{4}$$

where Q_{loss} is the lost charge (Ah), C is the battery capacity (Ah), and the self-discharge rate is expressed as a percentage per month. With C = 200 Ah and a self-discharge rate of 3% per month, Q_{loss} = 200 × 3/100 = 6 Ah per month. This charge loss is the reason why idle batteries still need to be charged and inspected periodically.

Table 5. Results of Data Verification with Formulas

Equivalent resistance (Ω)	Battery voltage (V)	Charging current (A)	Charge loss (Ah/month)
0.24	12	3.19	6

Table 6. SPSS Verification of the Formula Results (One-Sample Statistics)

Variable	N	Mean	Std. Deviation	Std. Error Mean
Resistance	1	0.260	.	.
Voltage	1	12.20	.	.
Current	1	3.20	.	.
Charge loss	1	3.04	.	.

3.2.3. Comparison of SPSS and Formula Results

The comparison between the SPSS results and the formula calculations is presented in Table 7.

Table 7. Comparison of SPSS and Formula Results

Parameter	SPSS result	Formula result	Difference
Equivalent resistance (Ω)	0.26	0.24	0.02
Battery voltage (V)	12.20	12	0.20
Charging current (A)	3.20	3.19	0.01
Charge loss (Ah/month)	3.04	6	2.96

Table 7 shows that the equivalent resistance, voltage, and charging current obtained from the formulas are almost identical to the SPSS results, with differences of 0.01–0.20. In contrast, the charge loss differs considerably (2.96 Ah/month) because the value processed in SPSS was not derived from the 200 Ah battery capacity. Since the one-sample test in Table 6 used a single data point (N = 1), the SPSS results are descriptive only and cannot be treated as a statistical test.

3.2.4. Validity and Reliability Tests

The results of the validity test using Pearson correlation are presented in Table 8.

Table 8. Validity Test Results (Pearson Correlation)

Variable	Statistic	Y	X1	X2	X3	X4
Y	Pearson Correlation	1	−0.998*	1.000**	1.000**	−1.000**
	Sig. (2-tailed)		0.037	.	.	.
	N	3	3	2	2	2
X1	Pearson Correlation	−0.998*	1	−1.000**	−1.000**	1.000**
	Sig. (2-tailed)	0.037		.	.	.
	N	3	3	2	2	2
X2	Pearson Correlation	1.000**	−1.000**	1	1.000**	−1.000**
	Sig. (2-tailed)	.	.		.	.
	N	2	2	2	2	2
X3	Pearson Correlation	1.000**	−1.000**	1.000**	1	−1.000**
	Sig. (2-tailed)	.	.	.		.
	N	2	2	2	2	2
X4	Pearson Correlation	−1.000**	1.000**	−1.000**	−1.000**	1
	Sig. (2-tailed)	.	.	.	.	
	N	2	2	2	2	2

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

An item is considered valid if the absolute value of the calculated r exceeds the critical r value. Table 8 shows that the correlation between Y and X1, −0.998 with N = 3, is significant at the 0.05 level (p = 0.037), and its absolute value slightly exceeds the critical r for N = 3 (0.997). The other correlations are ±1.000 with N = 2, so their significance cannot be computed and no meaningful critical r value can be determined. With such a small amount of data, the validity results cannot be generalised.

Table 9. Reliability Test Results

Cronbach's Alpha	Number of items
−2.031	5

The reliability coefficient categories are as follows: 0.80–1.00, very high reliability; 0.60–0.80, high reliability; 0.40–0.60, moderate reliability; 0.20–0.40, low reliability; and below 0.20, not reliable.

Table 9 shows a Cronbach's alpha of −2.031, far below the 0.60 threshold, so the instrument does not meet the reliability criterion. The negative value arises because the average inter-item covariance is negative and the amount of data is very small. Therefore, the validity and reliability results are treated as a limitation of this study, and its conclusions are based mainly on the direct observation data of the battery condition (Table 1 and Figure 1).

3.3. Discussion

The finding that the abnormal battery required a charging time of 13.3 h, twice that of the normal condition (6.6 h), is consistent with Huang and Li (2023), who showed that the constant-current charging curve can serve as a rapid indicator of the state of health of lead-acid batteries. The heat and odour of battery 3 are also consistent with the failure mechanisms of lead-acid batteries caused by ageing and high operating temperatures (Ruetschi, 2004; Prasad et al., 2023). This finding also agrees with Conradt et al. (2023), who concluded that capacity loss due to ageing is the main cause of starter battery failures in the field. Therefore, periodic monitoring of battery charging time and voltage should be included in the planned maintenance schedule of the engine room (Eriksen et al., 2021; Handani & Uchida, 2024).

3.3.1. Problem Handling

When the main engine could not be started, the incident was reported to the Second Engineer. The Second Engineer first informed the bridge that a problem with the main engine was preventing it from starting, and then directed an immediate inspection of the main engine battery. This inspection revealed the reason why the main engine could not perform its initial start.

3.3.2. Solution

After the Second Engineer identified that the main engine could not be started because its battery was damaged, the battery was replaced using the following steps.

3.3.3. Repair Procedure

a. **Documents prepared.** (1) The *manual book*, used to identify the battery specification and the risks that may arise during removal of the main engine battery. (2) The *paperwork*, covering authorisation from the Chief Engineer before the work is carried out.
b. **Battery removal.** (1) Disconnect the negative and positive terminals: begin by removing the cable, bolt, and clamp from the negative terminal of the battery, and then remove the positive terminal. (2) Lift the battery: after all parts are detached, lift the battery upright so that the electrolyte does not spill.
c. **Replacement of the damaged component.** After the battery has been inspected, the damaged battery is replaced with a new one that meets the manufacturer's specification.
d. **Reinstallation.** (1) Lift the battery upright so that the electrolyte does not spill. (2) Connect the positive and negative terminals: begin by fitting the cable, bolt, and clamp to the positive terminal, and then connect the negative terminal.
e. **Completion of the procedure.** Carry out monitoring and adjustment by ensuring that (1) all cables, bolts, and clamps are properly fitted; (2) the positive and negative cables are not reversed; and (3) the battery electrolyte is filled to the correct level.

3.3.4. Implications and Limitations

In practical terms, the results indicate that the charging time and charging load of the battery can be used as simple indicators to detect the deterioration of a starter battery before a starting failure occurs. Battery voltage, charging time, and physical condition should be recorded routinely in the planned maintenance system, and condition monitoring can help the engine crew determine the right time to replace batteries (D'Orazio et al., 2020; Koçak et al., 2023).

This study has several limitations. The data came from a single ship and a single starting failure, the number of measurements per condition was small (N = 6), the Wilcoxon test statistics (Z value and significance) were not available, and the validity and reliability tests did not meet the criteria. Future studies should use larger datasets, involve several ships, and measure battery health parameters directly, such as internal resistance and actual capacity.

4. CONCLUSION

Based on the results and analysis of the factors causing difficulty in the initial start of the main engine of the AHTS SK Canopus, the following conclusions can be drawn.

1. The main factor causing difficulty in the initial start of the starboard main engine of the AHTS SK Canopus was a battery that no longer met the specification because it had exceeded its service life. This condition was indicated by insufficient starting voltage, a charging time that increased to 13.3 h (normal 6.6 h), a charging load that increased to 6.43 A (normal 3.18 A), and physical symptoms of heat and odour. After the battery was replaced according to the manufacturer's specification, the charging time decreased to 3.3 h, the charging load to 1.60 A, and the statistical indicators returned to those of the normal condition.
2. Difficulty in the initial start of the main engine has significant implications for the operation of the AHTS SK Canopus, including delays to the operating schedule, an increased risk of overall engine malfunction, and potentially higher maintenance costs due to repeated starting attempts. This shows the importance of effective preventive and corrective actions to minimise negative impacts on operational efficiency and safety.
3. Periodic inspection of battery voltage, charging time, and physical condition within the planned maintenance system, together with replacement of batteries before they exceed their service life, is recommended to prevent similar failures. Future research should use larger datasets and involve more than one ship.

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