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Method for FTA (Fault Tree Analysis) combined with FMECA (Failure Mode and Criticality Analysis) on vessels focused on improving Reliability in Pneumatic Equipment Maintenance – A Case Study

Namir Furtado Vieira Júnior
Universidade Católica de Petrópolis-UCP, Brazil. E-mail: namir.42140089@ucp.br

José Cristiano Pereira
Universidade Católica de Petrópolis-UCP, Brazil. E-mail: josecristiano.pereira@ucp.br

Effective maintenance of marine equipment is crucial to increasing ship operability rates. Therefore, it is essential to invest in maintenance to ensure service quality. Developing efficient maintenance that manages the survival of the equipment and minimizes its failure can maximize the quality of services and meet the expectations of companies. Using FTA and FMECA can help assess the system's reliability and identify failures and risks in the project from a vision focused on reliability and criticality. This study aims to propose a method for FTA (Fault Tree Analysis) combined with FMECA (Failure Mode and Criticality Analysis) on vessels focused on improving Reliability in Pneumatic Equipment Maintenance. Through a case study, it demonstrates that the combination of FTA and FMECA can help identify, analyze, evaluate, and treat risks. It identifies and classifies the critical pneumatic equipment of the engine, presenting the failure modes in terms of safety, environment, production losses, and maintenance costs. A case study was conducted on a vessel with a team of experienced stakeholders working together and sharing experiences in elaborating first on the FTA and then the FMECA.
As a result, risks and response actions were identified. One of the risk response actions was the reduction of condensate in the compressed air networks resulting from installing the Air Dryer system, generating savings in engine parts, and increasing the vessel's operability. The study shows that using the Air Dryer helps maintain pneumatic equipment and remove condensate. It was observed that some vessels do not use this system, demonstrating the need for improvements in maintenance and design. The contribution is relevant for maritime support companies in general and the academy. In addition to ensuring the continuous improvement of the maintenance program, its results can serve as a basis for future studies. The study can also impact vessel maintenance processes and help understand performance and safety during operation. Although carried out on a specific vessel, it can be generalized to other vessels and fields of work whose safety is affected by similar risks, resulting in waste, rework, and unnecessary energy consumption. The study may change the practice and thinking of professionals who deal with PFMEA on ships.

Keywords: Air Dryer, Equipment Maintenance, Condensate, Ships and FMECA.

1. Introduction

According to Petrobras, "the current scenario is marked by an unprecedented combination of oil price instability, surplus supply in the market, and a strong contraction in global demand for oil and fuels. These new measures involve reducing oil production, postponing cash outlay, and cost reduction". With this, offshore support companies are preparing to face uncertainties, with the instability of the price of a barrel of oil and the global recession generated by the war between Russia and Ukraine, increasing the need for offshore companies to reduce their costs, increasing or maintaining productivity. With the current scenario of an increasingly globalized world, organizations observe the need to adapt to the growing changes by submitting their employees to develop new skills and propose considerable changes in management processes. Based on this scenario, there was a need for a critical look at maintenance on offshore vessels. The vessel object of this study has a critical problem concerning excess condensate from the compressed air system (main compressors) used in its equipment. The presence of condensate affects the vessels' equipment, mainly their combustion engines, which need compressed air for starting and protection equipment (oil mist detector, shut-off valve, and others). The authors could not identify previous studies focused specifically on the application of FTA and FMECA to identify risks in pneumatic equipment maintenance in vessels.
To identify the potential causes of pneumatic equipment failures, this study used a combined application of FTA and FMECA, which allowed the study team to better identify risks and the respective responses required to improve reliability in the pneumatic equipment maintenance. The application of the method was successful leading to reduction and warning of risks caused by condensate in equipment, reduction of equipment

maintenance costs, reduction of vessel downtime, reduction of hours worked by the maintenance team, and reduction of damage to equipment. The study provided responses to the following questions:

Question 1: What are the potential causes of equipment failure due to condensation from air lines?

Question 2: Does reducing condensate in compressed air networks generate savings in expenses by purchasing spare parts for engines?

Question 3: Does reducing condensate increases the vessel's serviceability rating?

Section 1 shows the introduction. Section 2, Literature Review, covers maintenance management, equipment reliability, condensate reduction on vessels, FMECA and FTA in assessing vessel reliability. Section 3 Methodology. Section 4 Results and Section 5 Conclusion.

2. Literature Review

2.1.Vessel Maintenance Management

According to Boeira (2022), the availability of assets has become an essential factor within organizations that increasingly aim for profit. Maintenance needs to control a series of processes to establish service routines, analyze asset behavior, maneuver and deploy teams of technicians and maintainers, collect and analyze data, and control resources to ensure maximum efficiency in the process with the lowest possible cost to achieve this goal. The best way to get good results is by using methodologies that aim to manage this multitude of processes.

According to Freitas (2022), to better develop organizational maintenance, it is necessary to effectively implement methods and tools to develop maintenance planning and control appropriately.

Still, according to Vitonto and Regattieri (2021), the partnership between production and maintenance is fundamental in this path. It can occur by forming teams in specific areas that can be used for joint analysis of failures, chronic problems, equipment performance, planning of services and even a daily schedule.

According to the Brazilian Association of Technical Standards (NBR 5462, 1994), maintenance is defined as a combination of all technical and administrative actions, including supervisory ones, intended to maintain or restore an item to a state in which it can perform a required function. The role of equipment maintenance is an essential component of the industry whose main objective is to maximize production yield. Equipment not working as specified can negatively influence production, frustrating the company's objectives (O'donovan et al., 2015). In this context, the objective of maintenance is to preserve the system and product functions throughout its life cycle (Vogl; Weiss and Helu, 2019). The high workload, the pressure to quickly solve problems, and the great responsibility for operational processes make technicians, supervisors, planners, and other employees susceptible to mental exhaustion (Vaportec, 2020). Old and obsolete equipment, equipment failures due to lack of preventive maintenance, sudden stops for repairs, and the consequent rush or urgency to carry out interventions can lead to hasty decision-making. It can lead to accidents at work and more significant material losses resulting from the attempt to use improvisations to solve problems (Indumak, 2021). This leads to reducing production costs, and since corrective maintenance is a representative portion of these costs, its reduction is paramount. According to (Martins, 2019), in the last 20 years, the maintenance sector has evolved like never before. These changes are due to a much more complex design, new maintenance techniques, a focus on maintenance organization, and an increased diversity of physical items, such as facilities and equipment.

2.2.Reliability in Equipment Maintenance on Vessels

Reliability is essentially vital for vessel maintenance studies.

According to Machado (2022), the reliability of propulsion shaft systems is a significant concern for ocean-going vessels, as repairs in the middle of the ocean can be time-consuming and spare parts must be available. An efficient critical parts inventory system where the purchasing department can work directly with the maintenance sector can help a lot in the availability of parts on board the vessel, thus improving reliability and operating conditions during a certain period.

2.3.Reduction of Condensate in Compressed Air Distribution on Vessels

According to Catermo (2022), air dryers of different sizes, types, models, and applications have become an excellent solution to problems caused by excess ambient humidity due to climatic or process conditions, being the most effective and robust mechanism to combat high humidities.

According to Viana (2017), air quality control is one of the fundamental steps in production processes that use air to control the amount of moisture in products or raw materials.

Removing this moisture from compressed air is essential to prevent machines and pneumatic tools from premature wear or damage (Kim et al., 2014). According to Bu-Gi et al. (2015), condensation is produced when the temperature at the compressor outlets and the air humidity is higher. The presence of water in the compressed air system generates complications both in the pneumatic circuit itself and in the application of air. This contaminant (water vapor or condensate) damages the paint finish, produces oxidation of pipes and check valves, reduces the durability and sealing of pneumatic cylinders, and destroys the lubrication film of tools and other mechanisms in contact with contaminated air (Citisystems, 2019).

The air has water vapor that can condense due to the variation in pressure and temperature along the compressed air distribution network. Drains and water-separating filters have the role of removing this condensate from the pneumatic line. Gresh apud Coradi (2011) states that purchasing a compressed air dryer is a high investment for the company. A dryer can represent 25% of the total value of the compressed air installation. However, the cost of acquiring the dryer is offset by its numerous benefits, minimizing the damage caused by humid air, such as replacing pneumatic components, the impossibility of using air in some operations, and the waste generated in the production of products. Given the above, it can be concluded that using the dryer benefits the system.

2.4.FMECA in the Assessment of Equipment Reliability on Vessels

FMECA, used in the reliability evaluation, has started to be used in different sectors of the industrial branch. In the naval sector, for example, it has made it possible to reduce costs, especially in the vessel maintenance sector. A case study occurred in 2022 of a large North American company in the naval sector, carried out on board an Offshore support vessel, linking the FMECA to the evaluation of the reliability of equipment on vessels, allowed the evaluation of the immediate and subsequent effects of each of the failure modes of each item belonging to the equipment used on the vessels. It reduced unwanted downtime of equipment, reduced operating and maintenance costs, and increased safety for employees and teams involved in maintenance activity. It increased the useful life of equipment and Components.

2.5. FTA in the Assessment of Equipment Reliability on Vessels

According to Nilton Oliveira (2022), due to the failure that occurred in a set formed by a centrifugal compressor and a steam turbine (both pieces of equipment also used on vessels), older machines have failed more constantly, reducing the operational reliability of the system, causing production losses and high maintenance costs. The author conducted an analysis of the failure that occurred in a centrifugal compressor (also used on ships), to explore the use of the Reliability tool, the Fault Tree Analysis - FTA - Fault Tree Analysis, evaluating the applicability of the tool and its contribution to obtaining better reliability of process industry equipment. The conclusion is that the FTA tool was adequate in this evaluation for this compressor since in this study, it was possible to evaluate the cause of the failure due to the high oil consumption that made the machine unavailable in an objective and effective way. This shows why the fault tree analysis has great relevance in analyzing this type of event and great applicability in the Onshore and Offshore industry.

Daya and Lazakis (2023) used a novel approach to system reliability analysis using DFTA, FMECA, and BBN applied to 4 DGs was conducted. The outcomes provide insight into faults and component criticality to vessel maintenance and availability.

Kaushik and Kumar (2023) proposed an integrated intuitionistic fuzzy fault tree and Bayesian network-based method for system failure probability evaluation in case of imprecise and insufficient failure data. Root causes of the 'parted rope injury during ship mooring operation' are obtained using fault tree analysis.

According to Dennis (2013), in a study on a liquefied natural gas carrier vessel, a positive effect emerged in evaluating the reliability of the equipment that governs the emergency valves using an FTA tool to evaluate the failure in the fluid storage system. Hydraulic.

The combination of two basic events that caused this was evaluated by fault tree analysis. This study served to increase the reliability and be able to determine the probability of occurrence of failure.

3. Methodology

The study was carried out on an AHTS (Anchor Handling Tug Supply). It is a multipurpose vessel built for Offshore type operations. It is used in operations such as anchoring maneuvers, towing, pull back, mobilization and demobilization of platforms, firefighting, water supplier, diesel, and other products. Initially a literature review was conducted focused on standards, manuals, and papers. A Stakeholders Meeting was conducted to prepare the Equipment Hierarchical Structure and FTA. Based on the FTA and the Structure the FMECA was prepared. The Risk Responses were defined and then implemented. Finally validation of results was done by monitoring maintenance and spare parts. The flowchart shows the steps followed in the study of Figure 1.

Fig. 1. Method Flowchart

3.1. Population and Sample

The sample was one specific vessel AHTS (Anchor Handling Tug Supply). Managers, Coordinators, Engineers, Supervisors, and leaders shipped from the Machinery sector participated in the study. The team had the participation of 11 professionals from different segments, mainly in the maintenance and safety segment. These stakeholders were selected based on their expertise in a specific domain.

3.2 Collected Data

For data collection, meetings were held with the maintenance and operations department and with the ship's engine crew to learn about the application of the FMECA.

3.3 Analyzed Data

Among the professionals who participated in the study, it was possible to assess that the areas with the most significant participation were Maintenance and Safety. The data were analyzed through the development and application of the FMECA.

3.4 Fault Tree Development and Application (FTA)

In order to create the Fault Tree, the hierarchical structure of equipment was defined. It was focused on the critical components using logic gates, carrying out an approach that allowed the identification of the root cause of a failure through a diagram. Fig 2 shows the hierarchical structure of the equipment and Fig 3 the FTA.

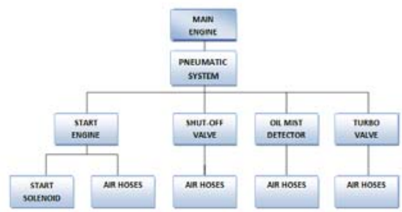

Fig. 2. Hierarchical structure of equipment for FMECA identification

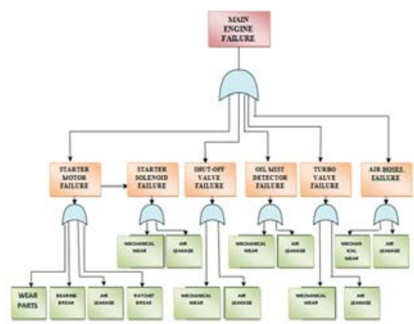

Fig. 3. FTA of the equipment for FMECA identification

Adapted from the chart by Smith and Keith (2008), the Effect x Impact Matrix was used, where on a scale of 1, 2, 4, 6, 8, and 10, from an arithmetic mean of the values, it is possible to calculate the impact of failure mode. Table 1 shows the Impact or severity of failure (S).

EFFECT	CATASTROPHIC 10	CRITICAL 8	HIGH 6	MODERATE 4	LOW 2	NO IMPACT 1
HEALTH / SAFETY	MORE THAN 10 DEATHS	FROM 1 TO 10 DEATHS OR PERMANENT DISABILITIES ACCIDENTS	ONE DEATH OR PERMANENT DISABILITY ACCIDENT	ACCIDENT WITH LEAVE	ACCIDENT WITHOUT LEAVE	NO PERSONAL INJURY
ENVIRONMENT	OF GREAT MAGNITUDE AND EXTENSION WITH IRREVERSIBLE DAMAGE	OF HIGH MAGNITUDE AND DIFFICULT TO REVERS, WITH RISK OF IRREVERSIBLE DAMAGE	OF CONSIDERABLE MAGNITUDE AND EASY TO REVERS	OF CONSIDERABLE MAGNITUDE BUT REVERSIBLE WITH MITIGATION ACTIONS	SMALL MAGNITUDE WITH IMMEDIATE ACTIONS	NO ENVIROMENTAL DAMAGE
PRODUCTION	IMPACTS GREATER THAN US$ 1,000 MM	IMPACTS BETWEEN US$0,501 MM AND US$1,000 MM	IMPACTS BETWEEN US$ 0,201 MM AND US$ 0,500 MM	IMPACTS BETWEEN US$ 0,051 MM AND US$ 0,200 MM	IMPACTS UNTIL US$ 0,050 MM	WITHOUT FINANCIAL IMPACTS
REPAIR COST	COST GREATER THAN US$ 500.000	COST BETWEEN US$ $ 500.000 AND US$ 100.000	COST BETWEEN US$ $ 100.000 AND US$ 50.000	COST BETWEEN US$ $ 50.000 AND US$ 10.000	COST LESS THAN US$ 10.000	NO REPAIR COST

Tab. 1. Impact or severity of failure (S)

Table 2 shows the frequency of failure occurrence (O).

SCORE	FAILURE FREQUENCY (O)
10	O ≤ 1 MONTH
9	O ≤ 6 MONTHS
8	O ≤ 1 YEAR
7	1 YEAR < O ≤ 2 YEARS
6	2 YEARS < O ≤ 4 YEARS
4	4 YEARS < O ≤ 6 YEARS
2	6 YEARS < O ≤ 8 YEARS
1	O > 8 YEARS

Tab. 2. Failure Frequency (O)

Table 3 shows the Degree of Detection on a scale that goes from a Very high probability of detection to an unlikely probability.

SCORE	FAULT DETECTION (D)
10	IMPROBABLE PROBABILITY
9	REMOTE PROBABILITY
8	VERY SMALL PROBABILITY
6	LOW PROBABILITY
4	MODERATE PROBABILITY OF DETECTION
2	HIGH PROBABILITY OF DETECTION
1	VERY HIGH PROBABILITY OF DETECTION

Tab. 3. Fault Detection (D)

Table 4 shows the RPN, which is the multiplication of the Severity, Occurrence and Detection. The risk priority degree is calculated, ranging from Very Low (0) to High (1000).

RISK	RPN			
	HIGH	MEDIUM	LOW	VERY LOW
	501-1000	101-500	51-100	0-50

Tab. 4. RPN

The criticality matrix is shown in Table 5. The objective is to understand the effects and risks a particular part can cause in the equipment. This Matrix will indicate a specific letter according to the level of the proposed Risk Range, ranging from High (letter A) to Not Classified (letter E), and will serve as a basis for classifying the parts under analysis.

CRITICITY MATRIX						
	CRITICALITY	RISK RANGE	HEALTH/SAFETY	ENVIROMENT	PRODUCTION	REPAIR COST
A	HIGH	RPN > 500	S = 10	S = 10	S = 10	S = 10
B	MEDIUM	RPN > 100 RPN ≤ 500	S = 8	S = 8	S = 8	S = 8
C	LOW	RPN > 50 RPN ≤ 100	S = 6	S = 6	S = 6	S = 6
D	VERY LOW	RPN > 10 RPN ≤ 50	S = 4	S = 4	S = 4	S = 4
E	NOT CLASSIFIED	RPN ≤10	.	.	.	.

Tab. 5. Criticality Matrix

According to the criticality class table in obtained from Table 5, the types of maintenance and approach methods are defined for each type of part as shown in Table 6.

CLASS OF CRITICALITY	TYPE OF MAINTENANCE	APPROACH METHOD
A	PREDICTIVE (OE PREVENTIVE WHEN PREDICTIVE IS NOT POSSIBLE)	BASED ON MONITORING AND TIME
B	PREVENTIVE AND INSPECTIONS	BASED ON TIME AND CONDITIONS
C	CORRECTIVE (PLANNED)	BASED ON INSPECTION
D	CORRECTIVE (UNPLANNED)	BSED ON BREAKAGE
E	WITHOUT MAINTENANCE ACTION	N/A

Tab. 6. Criticality Class / Type of Maintenance / Approach Method

The instruments that are part of the pneumatic subsystems of the main engine under study and their functions, potential failure modes, and effects were identified and defined, as shown in the Table 7.

NSTRUMENT	FUNCTION	FAIL MODE	FAILURE EFFECT
MAIN ENGINE	VESSEL NAVIGATION	ENGINE BREAKDOWN	LIFESPAN
		MECHANICAL WEAR	WEAR
		ELETRIC FAILURE	EXCESS OF CONDENSATE
		LEAKS	
		FAILURE SENSORS	
START ENGINE	ENGINE DRIVE	RATCHEAT BREAK	LIFESPAN
		WEAR PARTS	WEAR OF USE
		MECHANICAL FAILURE	EXCESS OF CONDENSATE
		BEARING BREAK	
		AIR LEAKAGE	
START SOLENOID	ENGINE DRIVE	MECHANICAL WEAR	OBSTRUCTION
		AIR LEAKAGE	EXCESS OF CONDENSATE
			ELECTRICAL FAILURE
AIR HOSES	COMPRESSED AIR CONDUCTION	MECHANICAL WEAR	WEAR OF USE
		AIR LEAKAGE	EXCESS OF CONDENSATE
SHUTT-OFF VALVE	ENGINE PROTECTION	MECHANICAL WEAR	WEAR OF USE
		AIR LEAKAGE	EXCESS OF CONDENSATE
OIL MIST DETECTOR	ENGINE PROTECTION	MECHANICAL WEAR	WEAR OF USE
		AIR LEAKAGE	EXCESS OF CONDENSATE
TURBO VALVE	PERFORMANCE INCREASE	MECHANICAL WEAR	WEAR OF USE
		AIR LEAKAGE	EXCESS OF CONDENSATE

Tab. 7. Form FMEA

4. Results

Historical data were collected referring to equipment breakdowns and failures and the periodicity of maintenance. The FMEA tool was applied, evaluating and determining the impacts of failures, their frequencies, and their probability of occurrence. The degrees of risk priorities for each instrument and their failure modes were calculated, finally classifying each asset's risk range and criticality, as shown in the Table 8.

PARTS/ INSTRUMENTS	HEALTH / SAFETY	ENVIRONMENT	PRODUCTION	REPAIR COST	IMPACT SEVERITY (S)	FAILURE FREQUENCY (O)	FAULT DETECTION (D)	RPN	DEGREE OF RISK	CRITICALITY
MAIN ENGINE	4	4	10	10	7	9	2	126	MEDIUM	B
START ENGINE	1	1	6	6	3.5	8	6	168	MEDIUM	B
START SOLENOID	1	1	4	6	3	8	6	144	MEDIUM	B
AIR HOSES	1	2	2	2	1.75	8	8	112	MEDIUM	B
SHUT-OFF VALVE	2	1	6	8	4.25	7	8	238	MEDIUM	B
OIL MIST DETECTOR	1	1	6	8	4	7	8	224	MEDIUM	B
TURBO VALVE	2	1	6	8	4.25	1	9	38.3	VERY LOW	D

Tab. 8. Form FMEA II

The maintenance plan strategies were determined, based on the criticality and risk classification previously obtained, as shown in the Table 9.

PARTS/ INSTRUMENTS	RPN	DEGREE OF RISC	CRITICALITY	MAINTENANCE STRATEGY
MAIN ENGINE	126	MEDIUM	B	PREVENTIVE AND INSPECTION
START ENGINE	168	MEDIUM	B	PREVENTIVE AND INSPECTION
START SOLENOID	144	MEDIUM	B	PREVENTIVE AND INSPECTION
AIR HOSES	112	MEDIUM	B	PREVENTIVE AND INSPECTION
SHUT-OFF VALVE	238	MEDIUM	B	PREVENTIVE AND INSPECTION
OIL MIST DETECTOR	224	MEDIUM	B	PREVENTIVE AND INSPECTION
TURBO VALVE	38,25	VERY LOW	D	CORRECTIVE (UNPLANNED)

Tab. 9. Form FMEA III

Finally, the maintenance plans were reviewed, and the results were analyzed quantitatively and qualitatively.

4.2 Metrics on Identified Risks

It was verified that using the FMECA tool helped the maintenance teams obtain traceable data on possible failures and risks caused by excess condensate in the networks. With the application of the FMECA tool, it was possible to identify the failure modes of the main parts of the main engine, with their degrees of risk and criticality, thus defining the best maintenance techniques and strategies. The results were identified and represented in three graphs: degree of risk, criticality, and maintenance strategy. The first graph, Fig. 4, presents the Degree of Risks of the failure modes, divided into high, medium, low and very low. A higher incidence is observed in the Medium risk degree.

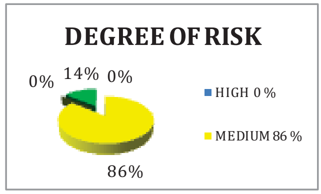

Fig. 4. Degree of Risk

The second graph, Fig. 5, shows the criticality of the equipment, divided into A, B, C, D, and E. A high potential impact on the engine's integrity is perceived, as 86% are of Medium criticality. Applying any of the following techniques is acceptable: preventive or predictive, improvement teams and teams, and analysis of failures by maintenance.

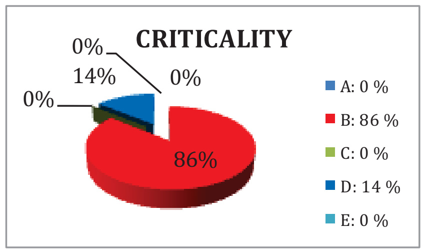

Fig. 5. Criticality

The third graph, Fig 6, presents the Maintenance Strategy: predictive, preventive, planned corrective, unplanned corrective, and without maintenance action. There is a greater incidence of Preventive Maintenance and Inspection.

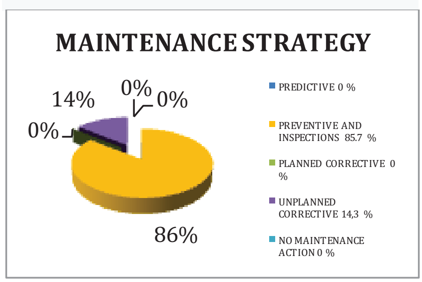

Fig. 6. Maintenance Strategy

4.3 Discussion of Results

As initially proposed, the results show, through a case study, that FMECA can help identify, analyze, evaluate, and treat risks. The combined application of FTA and FMECA allowed the study team to better identify risks and the respective responses required to improve reliability in the pneumatic equipment maintenance.

The study also shows the risks and response actions. One of the risk response actions was the reduction of condensate in the compressed air networks resulting from installing the Air Dryer system, generating savings in engine parts, and increasing the vessel's operability. The result was validated by the daily inspections carried out by the maintenance team. It could be noticed that the elimination of condensate led to the reduction in the frequency of maintenance in the pneumatic parts of the engine.

The result is significant when compared to previous published studies, as it brings an additional contribution in risk analysis that can impact vessel maintenance processes and help understand performance and safety during operation. As implications, it can be generalized to other vessels and fields of work whose safety is affected by similar risks, resulting in waste, rework, and unnecessary energy consumption.

5. Conclusion

This study proposed a method for FTA (Fault Tree Analysis) combined with FMECA (Failure Mode and Criticality Analysis) on vessels focused on improving Reliability in Pneumatic Equipment Maintenance. It focused on the use of FTA and FMECA tool to help the teams that work in the vessel's machinery sector and its maintenance sector to eliminate failures and risks and reduce and/or reset the condensate index in the compressed air networks from the vessel's main compressors, thus avoiding possible failures in equipment that need compressed air. Using the FTA and FMECA tool helped the teams learn more about the potential risks of failure caused by condensate in the compressed air networks and the correct maintenance used. Also, when evaluating the results, it can be stated that the efficiency of the Air Dryer on the vessel mentioned above was of great value to the maintenance sector, eliminating all condensate from the compressed air network. The efficiency can explain by the fact that the Air Dryer has for the vessel's primary compressed air system, reducing the wear of the parts of the combustion engines, which need compressed air for their operation. As for the contributions of this study, the following stand out: the decrease in the crew's workforce, the decrease in costs in the purchasing and maintenance sector, and mainly in the reduction of engine downtime due to unplanned corrective maintenance.

In response to Question 1: *"What are the potential causes of equipment failure due to network condensate?"* It was concluded that when using the FTA and FMECA tools, the main failures in the equipment are: Failure in the starter motor, failure in the starting solenoid, failure in the shut-off valve, failure in the oil mist detector, failure in the turbo valley and failure in the hoses of compressed air. In response to question 2, *"Does the reduction of condensate in compressed air networks generate savings in expenses with the purchase of spare parts for engines?"* It is concluded that with the reduction of condensate, there was also a considerable reduction in the wear and tear of parts that need to work directly with compressed air, thus generating a drop in the demand for parts requests for the company's purchasing sector. In response to Question 3: *"Does reduce condensate increase the vessel's serviceability rating?"* With the reduction of condensate and consequently the reduction of stoppages due to unplanned maintenance of the engines, there was better operational service, eliminating the downtime of the vessel (which entails a daily fine), and increasing the company's revenue.

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