# Analysis of Maintenance and Optimization Strategies for CENTAC Compressors

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**Abstract**: The oil and gas industry must continuously increase its requirements by implementing maintenance strategies for these systems to improve their availability and productivity. So Reliability is vital in the industry, as it ensures stable production processes, equipment performance, and compliance with quality standards. Our article evaluates the reliability of the engine compressor through diagnostic and statistical analysis, identifying the causes of failure and proposing improvements. It offers practical recommendations to optimize efficiency and maintain production continuity, providing practical advice for improving the reliability of motor compressors. Using diagnostic models, and statistical and probability analysis, we identify the main causes of failure and suggest improvements to improve engine compressor reliability. Our findings offer practical guidance for maximizing operational efficiency and maintaining production continuity.

*Keywords*: Reliability, Maintenance strategies, Compressors, Failure, Optimization

## 1. INTRODUCTION

Maintaining electromechanical equipment is essential for preserving the smooth running of production processes and ensuring customer satisfaction. The industrial maintenance discipline includes a variety of strategies and methods to provide maintenance, repair, and optimization of industrial equipment, whether electrical, mechanical, or a combination of both (Iméne and Khaled ; Bouami 2019). The objective is to deepen the basics of industrial maintenance, highlighting the various maintenance levels and their impact on the effective management of electromechanical equipment as shown in (GT 2023; Hocine 2023).

In most situations, failure models applied to reliability assessments come from statistical analysis of failures as suggested in (Halimi 2014; Héng 2015). This clarifies the abundant presence of probabilistic models dealing with parameter uncertainty in reliability distributions in specialized publications (Smith 2009; BENDJEROUDIB and MERRICHE 2016). Among the models frequently used to estimate these parameters are the exponential and the Weibull distributions. For this, we focus on estimating reliability using the Weibull distribution. Developing a preventive maintenance strategy requires identifying critical equipment, which must be the target of particular attention (MOTRANI, BENAICHA et al. 2016).

Studies (BENDJEROUDIB and MERRICHE 2016; MELLOUK and CHABBI 2023) have shown that FMEA (Failure Modes and Effects Analysis) method, contributes to the proper execution of maintenance by making it possible to examine the criticality of industrial equipment, and Pareto law analyzes, identifies, and prioritizes the problems or the causes that have the greatest impact on the industrial system (Grusenmeyer 2000; Raison 2000). These procedures contribute towards an optimization process.

To improve the overall performance of compressors, it is necessary to focus on the components that constitute them (HAFSI and ELDJOUDI 2017). MINITAB software will make it possible to analyze and generate relevant statistics on these components.

## 2- STUDY CONTEXT

### *2.1. Presentation*

This article discusses a study aimed at improving maintenance practices and strengthening the reliability of centrifugal compressors used in the GNL2Z (Liquefied Natural Gas) complex in Arzew-Oran, western Algeria.

These compressors, especially those installed in parallel, are crucial for the proper functioning of the complex. Therefore, their reliability is essential to maintain industrial operations continuously and efficiently. This experimental study examines different maintenance strategies for LNG2 compressors, such as preventive, condition-based, and corrective maintenance. It also focuses on failure and reliability analysis to determine the most effective approaches to optimize the management of these compressors. The main objective is to identify the causes of frequent breakdowns, evaluate the reliability of compressors, and propose solutions to improve their performance and durability.

### *2.2. Caractéristiques du moto compresseurs CENTAC*

The CENTAC compressor is a high-efficiency oil-free centrifugal compressor driven by a flange-mounted electric motor. The compressor and the drive motor are connected directly by a coupling. The complete equipment is mounted on a common rigid steel base plate with its own lubrication system, control system, and auxiliary devices.

**Table1.Characteristics of 2020J Motor Compressors.**

| **Flow rate ($m^3/h$)** | Max : 900 $m^3/min$<br>(31 783,2 $ft^3/min$)<br>Min : 180 $m^3/min$<br>(6 356,64 $ft^3/min$) |
|---|---|
| Height (mm) | 2285 |
| Rotational speed (m/s) | 2970 |
| Width (mm) | 3030 |
| Protection degree | IP23 |
| Temperature (°c) | 200 |
| Impeller diameter (mm) | 282 |
| Control frequency (HZ) | 50 |
| Noise level (dB) | 79 |
| Motor power (kW) | 430 |
| Voltage (V) | 380/415 |
| Weight (kg) | 5500 |
| Width (mm) | 1770 |
| Height (mm) | 2285 |

### *2.3. Structure data*

The FMEA method based on the data and the history of failures of the four air compressors (references 2020JA, 2020JB, 2020JC, and 2020 JD) operating in parallel within the Sonatrach LNG 2 complex since 1997, made it possible to understand the evolution of equipment performance and identify long-term trends in reliability.

#### A- Compressor 1

- Downtime is calculated by this equation:

$$TTR = \text{Date of start-up} - \text{Date of breakdown} \qquad (1)$$

TTR : Time To Repair.

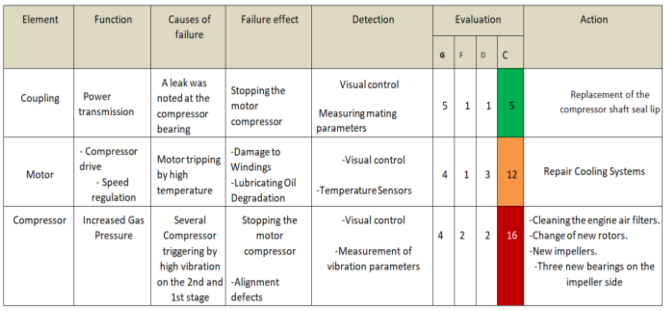
**Table 2. Compressor Downtime History 2020JA**

| **NB** | **Part of the equipment** | **Downtime (days)** | **NB** | **Part of the equipment** | **Down time (days)** |
|---|---|---|---|---|---|
| **1** | *Coupling* | 7 | ***13*** | Compressor | 32 |
| **2** | *Motor* | 1 | ***14*** | Motor | 36 |
| **3** | *Motor* | 1 | ***15*** | Motor | 20 |
| **4** | *Compressor* | 32 | ***16*** | Compressor | 63 |
| **5** | *Compressor* | 31 | ***17*** | Compressor | 5 |
| **6** | *Compressor* | 29 | ***18*** | Compressor | 19 |
| **7** | *Motor* | 29 | ***19*** | Compressor | 10 |
| **8** | *Motor* | 2 | ***20*** | Compressor | 5 |
| **9** | *Compressor* | 11 | ***21*** | Compressor | 12 |
| **10** | *Compressor* | 13 | ***22*** | Motor | 5 |

## 3- FMEA METHOD

Table 3. highlights the critical compressor and motor components, their functions, possible causes of failure, effects of these failures, detection methods, and necessary corrective actions. By following the recommendations for action, the risks of failure can be reduced, thereby ensuring more reliable and efficient operation of the 2020JA compressor.

**Table 3. FMEA Analysis of Compressor 2020JA**



| Element | Function | Causes of failure | Failure effect | Detection | Evaluation | | | | Action |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | G | F | D | C | |
| Coupling | Power transmission | A leak was noted at the compressor bearing | Stopping the motor compressor | Visual control<br>Measuring mating parameters | 5 | 1 | 1 | 5 | Replacement of the compressor shaft seal lip |
| Motor | - Compressor drive<br>- Speed regulation | Motor tripping by high temperature | -Damage to Windings<br>-Lubricating Oil Degradation | -Visual control<br>-Temperature Sensors | 4 | 1 | 3 | 12 | Repair Cooling Systems |
| Compressor | Increased Gas Pressure | Several Compressor triggering by high vibration on the 2nd and 1st stage | Stopping the motor compressor<br>-Alignment defects | -Visual control<br>-Measurement of vibration parameters | 4 | 2 | 2 | 16 | -Cleaning the engine air filters.<br>-Change of new rotors.<br>-New impellers.<br>-Three new bearings on the impeller side |

The interpretation of the criticality results in the table is as follows:

The highest criticality is for the Compressor (C = 16), which indicates that it presents the greatest risk and requires immediate attention. The actions listed are intended to address potential high vibration issues and component replacements.

The Engine has a criticality of 12, suggesting a moderate risk mainly due to temperature-related failures. Repairing the cooling system is an essential mitigation step.

The Coupling has the lowest criticality (C = 5), indicating relatively low risk, and a simple corrective action of changing the lip seal.

### B- Compressor 2

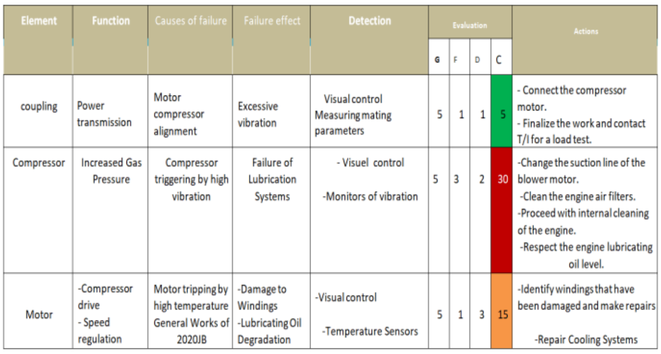
Criticality results in a FMEA analysis are used to identify and prioritize failure modes based on their overall impact on the system. Criticality results are calculated by multiplying the Severity (G), Frequency (F) and Detectability (D) values.

Coupling: Has low criticality (C = 2), indicating low risk. The corrective action is simple: check the electrical connections.

Compressor: At the highest criticality (C = 30), indicating a significant risk requiring immediate and various actions to avoid failure of the lubrication systems.

Engine: Has moderate criticality (C=15), suggesting moderate risk requiring repairs to damaged windings and cooling systems.

**Table 4. FMEA Analysis of Compressor 2020JB**

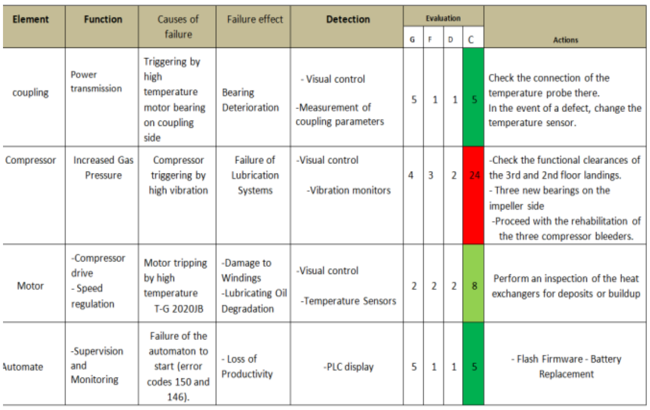


| Element | Function | Causes of failure | Failure effect | Detection | Evaluation | | | | Actions |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | G | F | D | C | |
| coupling | Power transmission | Motor compressor alignment | Excessive vibration | Visual control<br>Measuring mating parameters | 5 | 1 | 1 | 5 | - Connect the compressor motor.<br>- Finalize the work and contact T/I for a load test. |
| Compressor | Increased Gas Pressure | Compressor triggering by high vibration | Failure of Lubrication Systems | - Visuel control<br>-Monitors of vibration | 5 | 3 | 2 | 30 | -Change the suction line of the blower motor.<br>-Clean the engine air filters.<br>-Proceed with internal cleaning of the engine.<br>-Respect the engine lubricating oil level. |
| Motor | -Compressor drive<br>- Speed regulation | Motor tripping by high temperature General Works of 2020JB | -Damage to Windings<br>-Lubricating Oil Degradation | -Visual control<br>-Temperature Sensors | 5 | 1 | 3 | 15 | -Identify windings that have been damaged and make repairs<br>-Repair Cooling Systems |

### C- Compressor 3

From a Data of downtime history we presents FMEA on a model 2020JC compressor

**Table 5. FMEA Analysis of Compressor 2020JC**



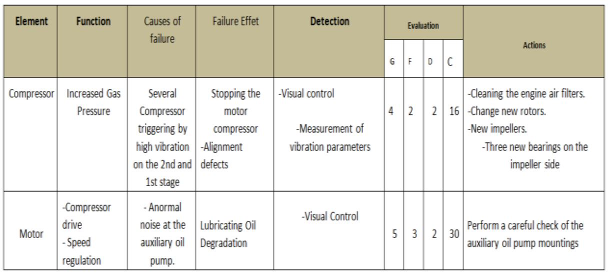
| Element | Function | Causes of failure | Failure effect | Detection | Evaluation | | | | Actions |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | G | F | D | C | |
| coupling | Power transmission | Triggering by high temperature motor bearing on coupling side | Bearing Deterioration | - Visual control<br>-Measurement of coupling parameters | 5 | 1 | 1 | 5 | Check the connection of the temperature probe there.<br>In the event of a defect, change the temperature sensor. |
| Compressor | Increased Gas Pressure | Compressor triggering by high vibration | Failure of Lubrication Systems | -Visual control<br>-Vibration monitors | 4 | 3 | 2 | 24 | -Check the functional clearances of the 3rd and 2nd floor landings.<br>- Three new bearings on the impeller side<br>-Proceed with the rehabilitation of the three compressor bleeders. |
| Motor | -Compressor drive<br>- Speed regulation | Motor tripping by high temperature T-G 2020JB | -Damage to Windings<br>-Lubricating Oil Degradation | -Visual control<br>-Temperature Sensors | 2 | 2 | 2 | 8 | Perform an inspection of the heat exchangers for deposits or buildup |
| Automate | -Supervision and Monitoring | Failure of the automaton to start (error codes 150 and 146). | - Loss of Productivity | -PLC display | 5 | 1 | 1 | 5 | - Flash Firmware - Battery Replacement |

Compressor (C=24): This failure has high severity, moderate frequency of occurrence and difficult detection, requiring immediate action to avoid major interruptions and costly repairs.

Coupling (C = 5), Motor (C = 8), Automation (C = 5): These failures have variable severity but a low frequency of occurrence and easy detection, suggesting regular preventive actions and checks to avoid problems.

### *D- Compressor 4*

**Table 6. FMEA Analysis of Compressor 2020JD**



| Element | Function | Causes of failure | Failure Effet | Detection | Evaluation | | | | Actions |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | G | F | D | C | |
| Compressor | Increased Gas Pressure | Several Compressor triggering by high vibration on the 2nd and 1st stage | Stopping the motor compressor<br>-Alignment defects | -Visual control<br>-Measurement of vibration parameters | 4 | 2 | 2 | 16 | -Cleaning the engine air filters.<br>-Change new rotors.<br>-New impellers.<br>-Three new bearings on the impeller side |
| Motor | -Compressor drive<br>- Speed regulation | - Anormal noise at the auxiliary oil pump. | Lubricating Oil Degradation | -Visual Control | 5 | 3 | 2 | 30 | Perform a careful check of the auxiliary oil pump mountings |

The criticality results show that the motor presents a higher risk (C = 30) than the compressor (C = 16). Therefore, although both components require corrective actions, special attention and frequent checks are crucial for the engine due to its potentially more serious impact on the system.

### *3.1 Analysis by Pareto's law*

The Pareto chart is a histogram representing data ranked in descending order of importance. It allows you to concentrate the actions that will have the greatest effect. The diagram below is the result of the Pareto analysis carried out on the compressor equipment. This analysis was carried out in the MINITAB environment, it highlights the most critical equipment.

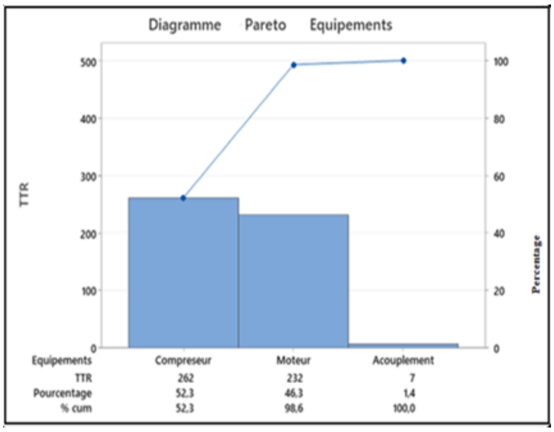


Figure 1. Pareto diagram equipment 2020JA.

The graph (Figure 1) indicates that compressors are the most common cause of failures, accounting for 52.3% of the total repair time. Engines come in second with 46.3% of total repair time. Couplings are the least common source of failures, accounting for only 1.4% of total repair time.

ABC categorization is a classification method based on the importance of equipment in terms of value, criticality or frequency of use. Here's how this could be applied to specific equipment:

- Category A: Compressor (52.3%) – High priority for maintenance and frequent inspections.

- Category B: Motor (46.3%) – Significant importance, requiring moderate management.

- Category C: Coupling (1.4%) – Less critical, can be managed with minimal resources.

The Pareto result of Moto-Compressor 2020JB

Here is the Pareto chart highlighting the priority items.

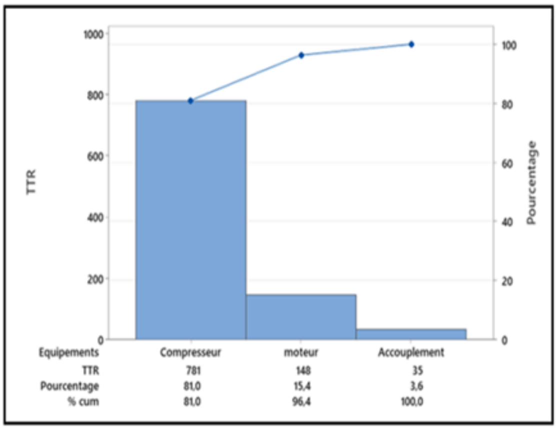


Figure 2. Pareto diagram equipment 2020JB

In this situation, the compressor is responsible for 81% of the total TTR (equation (1)). This means that this type of equipment is the most important in terms of repair time and requires specific attention.

### *3.2- ABC Categorization of 2020JB equipment*

- Category A : Compressor (81.0%) – Very high priority for maintenance and frequent inspections.

- Category B : Motor (15.4%) – Significant importance, requiring moderate management.

- Category C : Coupling (3.6%) – Less critical, can be managed with minimal resources.

The Pareto result of Moto-Compressor 2020JC

Here is the Pareto chart illustrating the main components to prioritize. The figure below shows the application of the Pareto principle on Equipment 2020JC.

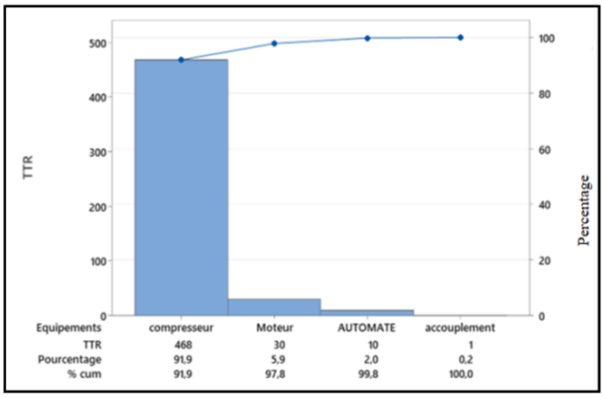


Figure 3. Pareto diagram equipment 2020JC

In the 3rd case 2020JC, the compressor alone represents 91.9% of the total TTR, which means it is extremely critical in terms of repair time and requires special attention.

### *3.3 ABC Categorization of 2020JC equipment:*

- Category A: Compressor (91.9%) – Very high priority for maintenance and frequent inspections.

- Category B: Motor (5.9%) – Significant importance, requiring moderate management.

- Category C: PLC (2.0%) and Coupling (0.2%) – Less critical, can be managed with minimal resources.

The Pareto result of Motor Compressor 2020JD Here is the Pareto diagram indicating components to prioritize. The figure below demonstrates the application of Pareto's law on Equipment 2020JD.

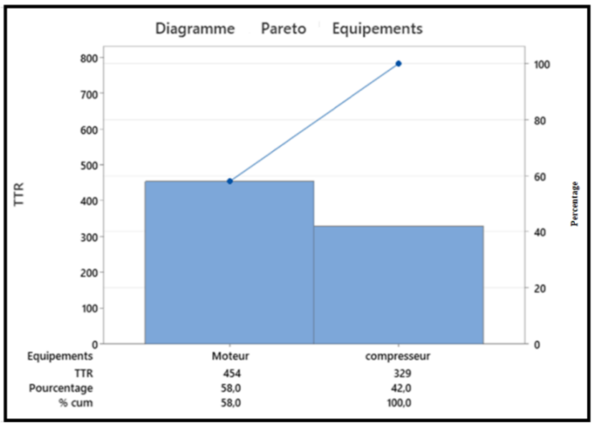


Figure 4. Pareto diagram equipment 2020JD

In this case of the 4th compressor 2020JD, the compressor and the engine together represent 100% of the total TTR. This means that these two types of equipment are the most critical in terms of repair time and require special attention.

ABC categorization of Equipment 2020JD:

Category A: Engine (58.0%) - High priority for maintenance and frequent inspections.

Category B: Compressor (42.0%) - Significant importance, requiring moderate management.

## 4- RELIABILITY STUDY

The results obtained by the FMEA diagnostic methods and Parto statistics show that the critical equipment targeted as a priority are: Motor compressors 2020JA, 2020JB, 2020JC and motor compressor 2020JD. For this, the study of the reliability of these four components by the Weibull law with the MINITAB statistics software will make it possible to better plan their maintenance and improve their performance.

### *4.1 Compressor 2020JA :*

The history of the Motorcycle compressor 2020JA using the TBF (Time Between Failure) calculations by equation (1) then we classify in ascending order as shown in the table :

*TBF=Date of Failure-Date of previous start-up* (1)

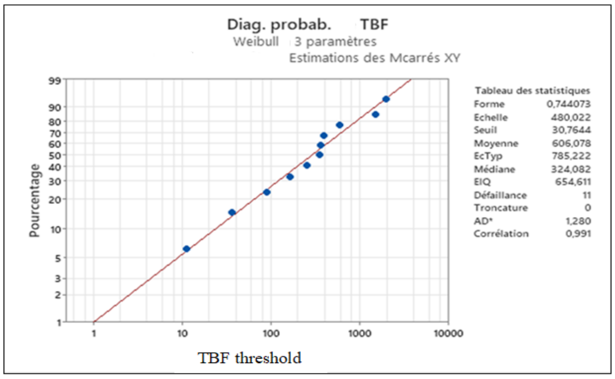
**Table 7. 2020JA Compressor Uptime**

| TBF Number | TBF (day) |
|---|---|
| 1 | 42 |
| 2 | 67 |
| 3 | 120 |
| 4 | 193 |
| 5 | 285 |
| 6 | 383 |
| 7 | 386 |
| 8 | 422 |
| 9 | 626 |
| 10 | 1527 |
| 11 | 2015 |

The estimation method: “Least squares (failure time X on rank Y” with the Weibull law with 3 parameters gave the following diagram :

This 3 parameters Weibull diagram is a graphical representation used to evaluate the reliability and lifespan of a product or system.

The shape of 0.744073 indicates a decrease in failures over time. This suggests that failures are more likely early in the life of the product or system.



| Tableau des statistiques | |
|---|---|
| Forme | 0,744073 |
| Echelle | 480,022 |
| Seuil | 30,7644 |
| Moyenne | 606,078 |
| EcTyp | 785,222 |
| Médiane | 324,082 |
| EIQ | 654,611 |
| Défaillance | 11 |
| Troncature | 0 |
| AD* | 1,280 |
| Corrélation | 0,991 |

Figure 5. Weibull Diagram Compressor 2020JA

*Estimation of parameters using the Weibull model*

The parameters obtained from the Weibull law are:

$\beta = 0{,}744073$ ; $\eta = 480.022$ ; $\gamma = 30.7644$

From these parameters and using equations ((2), (3), (4), we obtain the calculation results in the following table:

$$F(t) = 1 - R(t) = 1 - e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} \qquad (2)$$

Such as :

$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} \qquad (3)$$

F (t): probability that the system operates without failure up to time t.

R (t): reliability function; β: shape parameter (dimensionless) representing the rate of change of degradation; η: scale parameter (time unit); γ: location parameter (time unit)

$$\lambda(t) = \frac{F(t)}{R(t)} = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} \tag{4}$$

**Table.8 Calculated compressor Parameters 2020JA**

| Parameters | Calculation results |
|---|---|
| MTBF(Mean TBF) | 551.4545 days |
| Reliability R(t) | 34.56% |
| Failure function | 65.44% |
| Failure rate | 0.001518 failure/day |
| Failure frequency | 0.0005247 |

These parameters allow us to estimate essential reliability metrics, and support important decisions regarding maintenance, warranty and risk management (table 8).

### *4.2 Compressor 2020JB:*

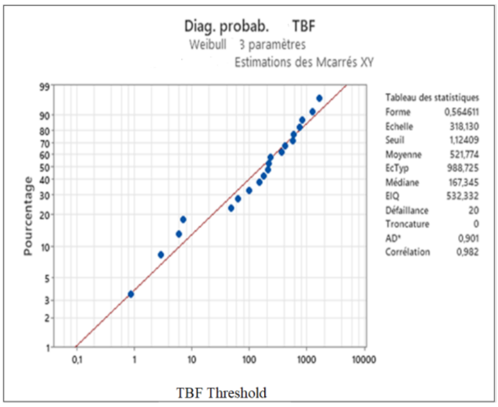


Figure 6. Weibull Diagram Compressor 2020JB

This Weibull diagram shows that the system studied undergoes a failure phase at the beginning of its life with a high initial rate which decreases over time. The average lifespan is approximately 522 days, with a median of 167 days. The fit of the Weibull distribution to the observed data is excellent.

Estimation of parameters using the Weibull model

The parameters obtained from the Weibull law are:

• $\beta = 0.564611$ ; • $\eta = 318.130$ ; • $\gamma = 1.12409$

### *4.3 Compresseur 2020JC*

The history of the Compressor 2020JC With the TBF calculations using the equation classified in crossing order are represented on graph below:

The simulation performed in MINITAB results in the following figure:

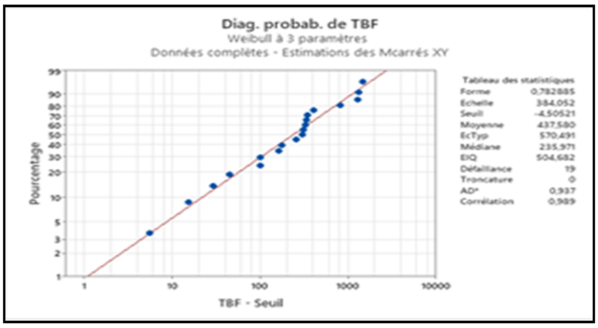


Figure7. Weibull diagram Compression block 2020JC

This Weibull plot shows that the studied system undergoes an early failure phase with a high initial failure rate that decreases over time. The average lifespan is approximately 438 days, with a median of 236 days.

Estimation of parameters using the Weibull model

The parameters obtained from the Weibull law are:

• $\beta = 0.782885$; • $\eta = 384.052$; • $\gamma = -4.50521$

### *4.4 Moteur of 2020JD*

According to the history of the 2020JD Moto-compressor Engine, the TBF calculations are represented on graph below::

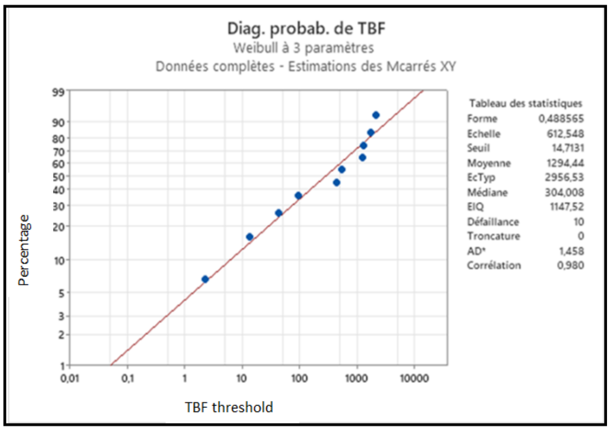


Figure 8**.** Weibull diagram Compression block 2020JD

The fitted curve (red line) follows the observed points (blue points) quite well, indicating that the 3-parameter Weibull model fits the data perfectly; it is confirmed by the high correlation (0.980) and a relatively low AD statistic (1.458).

The value of β (<1) suggests a decrease in the failure rate over time, which is typical in the early phases of a product or system's life.

## *4.* GRAPHICAL REPRESENTATION OF RELIABILITY AS A FUNCTION OF TBF

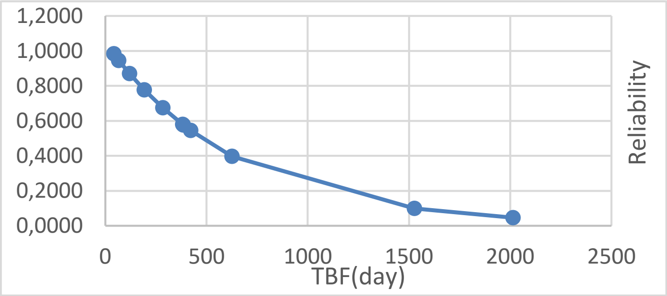


Figure 9. Reliability curve R (t) 2020JA

Compression block reliability is high initially and declines rapidly, indicating early failures. Then the decay slows down, showing that the remaining components are more durable, reaching a stable residual reliability over time.

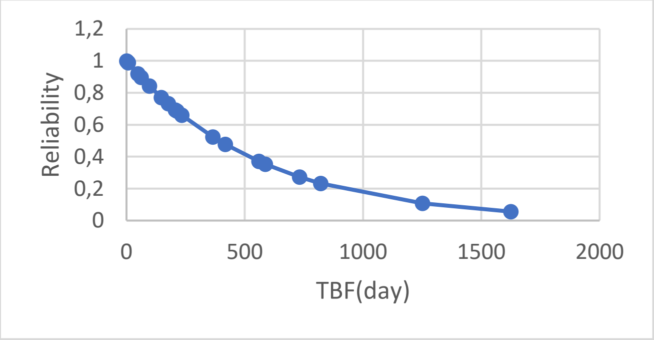


Figure 10. Reliability curve R (t) 2020JB

Compression block B exhibits high reliability initially, but suffers a sharp decline initially, marking initial failures. After this phase, the curve flattens, meaning better durability of the remaining components and stable residual reliability thereafter.

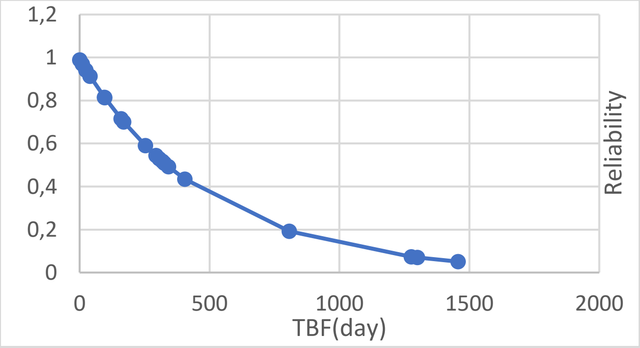


Figure 11. Reliability curve R (t) 2020JC

Compression block C starts with peak reliability that drops quickly due to early failures, then the curve stabilizes, indicating that working components are more robust, with stable residual reliability over time.

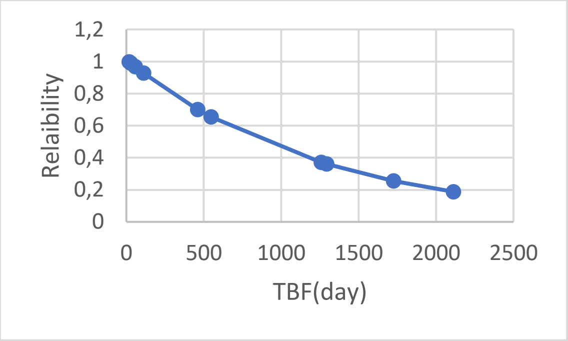


Figure 12**.** Reliability curve R (t) 2020JD

The reliability of the D engine is initially high but declines rapidly, revealing frequent initial failures. After this phase, the failure rate slows down, showing increased durability of the remaining components, with stable residual reliability thereafter.

## *5.* OPTIMIZATION

### *1- 1st Proposal*

After studying the reliability of the four compressors, we propose a solution to evaluate the desired reliability through regular systematic preventive maintenance and a defined periodicity to avoid their failures. In our case, we will try to evaluate the reliability over four stages from 70% to 85% the desired value. The following function allows you to calculate the maintenance period of the components:

$$T = \eta \times (ln\ (R(t))\hat{}(1/\beta) + \gamma \qquad (5)$$

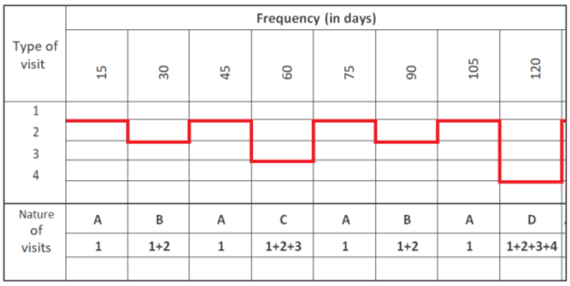
**Table 9. Intervention times**

| Reliability | T (compressor A) (days) | T (compressor B) (days) | T (compressor C) (days) | T (Motor D) (days) |
|---|---|---|---|---|
| 60% | 225.39 | 97.93 | 158.33 | 169.60 |
| 65% | 185.55 | 72.71 | 126.48 | 123.99 |
| 70% | 150.86 | 52.37 | 98.41 | 88.96 |
| 75% | 120.73 | 36.14 | 73.70 | 62.54 |
| 80% | 94.7067 | 23.45 | 52.03 | 43.14 |
| 85% | 75.52 | 13.86 | 33.20 | 29.57 |

To assess reliability between 75% and 85%, it is necessary to implement systematic interventions. Using the ABAC-ABAD method with a period of 15 days of systematic interventions, we can assess the reliability of these components at 75% with the following maintenance intervention planning (ABAC: Attribute-Based Access Control; ABAD: Attribute-Based Authorization Decision):

The following table presents systematic intervention planning.

**Table 10. Systematic intervention planning**



| Type of visit | Frequency (in days) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 |
| Nature of visits | A | B | A | C | A | B | A | D |
| | 1 | 1+2 | 1 | 1+2+3 | 1 | 1+2 | 1 | 1+2+3+4 |

1. 2020JB compression block: one intervention every 15 days

2. 2020JD engine: one intervention every 30 days

3. 2020JC compression block: one intervention every 45 days

4. 2020JD compression block: one intervention every 60 days

### 2- *2nd Proposal*

Using equation (2) with *t*=MTBF, the uptime (TBF) of each motor compressor, the reliability of the latter was calculated with the Weibull parameters using Minitab software.

| 2020 JA | |
|---|---|
| Shape | 0,939937 |
| Scale | 430,951 |
| Threshold | -9,30449 |

| 2020 JB | |
|---|---|
| Shape | 0,682507 |
| Scale | 212,687 |
| Threshold | 0,109322 |

| 2020 JC | |
|---|---|
| Shape | 0,815513 |
| Scale | 302,013 |
| Threshold | -6,22159 |

| 2020 JD | |
|---|---|
| Shape | 0,789848 |
| Scale | 288,316 |
| Threshold | -5,08070 |

The calculated values are summarized in the following table:

**Table 11. Reliability of motor compressors**

| Equipment | MTBF | Reliability R(t) |
|---|---|---|
| **2020JA** | 434.35 | 0.38 |
| **2020JB** | 291.57 | 0.39 |
| **2020JC** | 332.61 | 0.40 |
| 2020JD | 325.67 | 0.40 |

The reliability of all the compressors in parallel calculated with equation (3).

$$Rtotale = 0{,}86544365$$

The proposal of the engineers of the GNL2Z complex is to purchase a new compressor, two locations are considered for its installation.

### 3- *1st installation proposal*

Change of lowest reliability compressor: 2020JA. Assuming that the reliability of the new compressor is 0.90, the total reliability becomes: Rtotal= 0.97.

### 4- *2nd Installation Proposal*

Adding the new compressor to all the compressors in parallel. The total reliability becomes: Rtotal = 0.98.

The reliability of the two propositions is almost the same. Given the estimate, the first choice seems to be the best to save intervention time on the fifth piece of equipment and save maintenance costs.

## 6. CONCLUSION

The experimental study carried out made it possible to identify the main causes of LNG2 compressor failures and to evaluate their reliability. FMEA analysis and Pareto's law were used to identify critical failures and prioritize them. The results of the reliability study showed that the compressors have unacceptable reliability, but there are areas for improvement. The criticality analysis of components allowed to have a time window for programming effective maintenance activities and outlined failures and main events contributing to jeopardize the production process. Both proposed solutions to improve compressor reliability offer advantages and disadvantages that must be carefully evaluated before being implemented.

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