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Optimization of the Availability of Three-Phase Asynchronous Motors at Rubanimin by a Thorough Analysis of Recurring Failures

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Abstract
The industrial performance of the company **RUBAMIN**is based on the reliability of its critical equipment, notably the three-phase asynchronous motors. This study focuses on the diagnosis of repetitive failures of the "Slag" engine in order to optimize its availability. The methodology is based on a statistical analysis of the failure history using the **Weibull probability distribution**. This model allows to accurately determine the parameters of reliability R(t) , maintainability M(t) and availability A(t). By comparing theoretical results (failure rate and probability density) with operational reality, this project identifies performance gaps. The culmination of this work is the proposal for a revised maintenance strategy, moving from a reactive mode to a proactive approach adapted to real operating conditions.

Keywords: Asynchronous motor, Weibull's law, Reliability, Availability, Industrial maintenance, RUBAMIN.

Introduction

In the contemporary industrial landscape, three-phase asynchronous motors have established themselves as the pillars of production. Their predominance is explained by their intrinsic robustness, their competitive cost price and a simplicity of implementation that surpasses that of their direct competitors.

However, despite this recognized reliability, these machines are not immune to failures. They are subject to severe thermal, mechanical and environmental constraints that undermine their operational integrity.

Within the company **RUBAMIN**, the availability of these engines is a critical lever for profitability. The recurrence of certain breakdowns, persisting despite regular interventions, highlights a discrepancy between current maintenance strategies and the actual demands on the equipment. These repetitive stops do not only represent a technical challenge; they directly impact the overall performance and the annual balance sheet of the company.

The importance of three-phase asynchronous motors in modern industry and within the RUBAMIN company.

- **Problem Statement:** The persistence of breakdowns despite regular interventions, highlighting a gap between current maintenance strategies and the actual operational demands on the equipment.
- **Research Objectives:** To diagnose the root causes of failures in order to transform raw data into scientific knowledge to optimize maintenance.

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- **Research Questions (Analysis Axes):** The document defines three major axes, notably the identification of factors determining recurring breakdowns and the evaluation of the adequacy of the current maintenance strategy.

2. Literature Review

Although this section is not isolated under this exact title, the document contains the necessary foundations:

- **Analytical Model / Theoretical Framework:** The use of the **Weibull probability law** to determine parameters for reliability R(t), maintainability M(t), and availability A(t). It also relies on tools such as the **Pareto chart** and the **Ishikawa diagram**.

The present study is born from a desire to go beyond routine maintenance to establish a true culture of reliability. Based on the history of failures and the statistical tool of the Weibull law**, we propose to diagnose the deep origin of these failures. The objective is to transform raw data into scientific knowledge that allows maintenance optimization and ensures safe, stable and sustainable operation.**

Although asynchronous motors are renowned for their ease of maintenance, the operational reality at **RUBAMIN**reveals a persistence of breakdowns after intervention. The persistence of failures on RUBAMIN**'s asynchronous motors**, despite repeated technical interventions, highlights a complex situation that revolves around three major axes:

1. **Identification of the determinants of recurring failures** : It is necessary to determine whether the origin of the failures lies in the severe environmental constraints of the site, in an excessive use of the nominal capacities of the engines or in premature fatigue of the internal components. The challenge is to distinguish root causes from simple apparent symptoms.
2. **The evaluation of the adequacy of the current maintenance strategy** : The issue is based on the analysis of the effectiveness of the procedures in force. It is necessary to verify if the protocols applied respond to the physical reality of equipment wear or if they are akin to a systematic routine disconnected from the actual state of degradation of the machines.
3. **The transition towards a proactive and predictive maintenance model: The study focuses on the need to transform the failure management mode, from a sustained (curative) maintenance to an anticipatory approach. This involves the statistical exploitation of historical data to model the end of life of critical components and thus optimize intervention cycles before the onset of failure.**

In response to the axes of analysis defined in the problem, the following assumptions are formulated:

1. The recurrence of failures on asynchronous motors, and particularly on the "Slag" motor, would be the direct consequence of severe environmental constraints (dust, heat, vibrations) coupled with a fluctuating load regime, causing premature degradation of the bearings and stator insulation.
2. The current maintenance system is said to have limited effectiveness because it relies on a rigid or purely corrective systematic approach, which does not take into account the actual evolution of the failure rate λ (t) related to the specific operating conditions of RUBAMIN.
3. The statistical modeling of historical data by Weibull's law would allow for precise identification of the wear phase of the equipment. This scientific knowledge would make it possible to move towards proactive maintenance, where intervention intervals would be optimized to maximize availability while reducing premature replacement costs.

Methodology

The methodological approach adopted for this project is based on a rigorous technical analysis of RUBAMIN**'s engine fleet**, coupled with a statistical evaluation of reliability. It is divided into four structuring stages.

Research Methodology

- **Research Setting:** The study focuses on a specific 132 kW motor, representative of the operational demands at the RUBAMIN site.
- **Quantitative Data:** Use of failure history (13 failures recorded between January 2024 and June 2025) and the calculation of Time Between Failures (TBF) and Time To Repair (TTR).
- **Qualitative Data (Technical Analysis):** Identification of root causes such as industrial dust, humidity, and high ambient temperatures (50°C).
- **Secondary Data:** Consultation of technical data sheets on official manufacturers' websites to compensate for the lack of internal documentation.

In order to base our diagnosis on concrete bases, the study focuses on a three-phase asynchronous motor representative of site solicitations. The nominal characteristics are as follows:

Parameter	Value	Parameter	Value
Power (Pn)	132 kW	**Speed**	1480 RPM
Voltage (One)	373 – 456 V	**Isolation class**	F
Courant (In)	225 A	**Protection Index**	IP 55
Power factor	0.86	**Ambient Temperature**	50 °C

Table1 : Characterization of the reference equipment

This phase consists of listing the failures according to their nature to isolate the root causes. We distinguish two major categories:

A. Defects of mechanical origin:

- **Bearings (40 to 90% of cases):** Analysis of the rotor/stator interface, misalignment and degradation of internal/external rings.
- **Eccentricity:** Study of the rotor decentering (static, dynamic or mixed) that can lead to torque oscillations and, beyond 60% gap asymmetry, irreversible damage.
- **Flanges and Shaft:** Verification of positioning and structural integrity.

B. Defects of electrical origin:

- **Stator Circuit:** Diagnosis of short circuits between windings, phase-frame defects and aging of insulators under thermal stress.
- **Rotor Circuit:** Identification of short-circuit bar or ring breaks causing electromagnetic asymmetry.

The methodology integrates the impact of critical external factors at RUBAMIN. We will evaluate how permanent exposure to **dust**, moisture and high ambient temperatures **50°C accelerates the** deterioration of the cylinder head and windings, despite the protection class IP 55.

The company is currently using a redundancy solution (2 to 3 engines in alternate failover). Our methodology will analyze the latent risks of this practice:

- Corrosion of the contacts at shutdown.
- Moisture absorption by non-powered windings.
- Silent degradation of isolation.

The core of the analysis is based on the processing of failure history by the **Weibull law. By calculating the shape parameter** β, we will determine if the engine fleet undergoes:

1. Youth failures (installation/manufacturing issues).
2. Random failures (sudden breakdowns).
3. Marked wear (end of life of components).

II. Presentation of results and discussion

2.Analytical Approach

This section analyzes the critical failures of RUBAMIN**'s engine fleet** (pumps, overhead cranes, etc.) by highlighting a phenomenon of **cascading failures. The study identifies dust as the major triggering factor: its accumulation slows down the rotor, causing premature bearing wear and even shaft blockage. This mechanical blockage induces a critical thermal elevation that directly threatens the integrity of the stator winding and terminal box. In the latter case, the fusion of insulating elements (connecting shoes) generates short circuits between phases, making the failure irreversible without a heavy intervention.**

The analysis of the history of failures at **RUBAMIN**allows for drawing up the following synoptic table, which will serve as a basis for developing the new maintenance plan:

Type of Breakdown	Root Cause identified	Technical Consequence
Wear on bearings	Excessive dust infiltration	Resistance to pivoting and blocking of the rotor.
Thermal overheating	Mechanical blockage or overload	Deterioration of the insulation and burning of the windings.

Default Terminal box	High intensity/ Heat	Fusion of the lugs and short-circuit between phases.

Table 2 Table (Ideal for clarity in an article)

The inventory of recurring breakdowns within the company **RUBAMIN**reveals a particular vulnerability of asynchronous motors to their operating environment. The diagnosis highlights three major pathologies:

1. **Mechanical degradation:** Fouling by industrial dust alters the kinematics of the bearings, leading to galling.
2. **Thermal stress: As** a direct result of mechanical stresses, excessive heating degrades the electromagnetic properties of the stator.
3. **The failure of connectors: The terminal box constitutes a critical point where thermal and electrical stresses meet, causing the fusion of polymer materials and major insulation defects.**

II.2.1. Analysis of the failure history of the asynchronous motor SLAG

For a period ranging from 01/28/2024 to 06/10/2025, we have identified a total of 13 recurring breakdowns, grouped in Table 1:

Table3. Three-phase Asynchronous Motor 132 kW (Slag Motor) failure history

Date	Hours	Cause or failures	Maintenance time
28/01/2024	08h45'	Bearing defect.	2h30
15/02/2024	10h20'	Terminal plate burn (R phase).	1h45
27/03/2024	13h10'	General abnormal overheating	2h00
10/05/2024	09h30'	Rear bearing defect.	3h00
22/06/2024	14h50'	Neutral terminal burn	2h15
30/07/2024	07h15'	Overheating after extended start.	1h30
09/09/2024	16h05'	Accelerated wear of the front/rear bearing	3h20
18/11/2024	11h40'	Intermittent overheating.	1h10
05/12/2024	15h25'	Cable disconnection + burn	2h40
28/01/2025	20h10'	Bruit de grattement ► sudden stop	3h15
07/03/2025	11h25'	Prolonged overheating	2h20
13/04/2025	16h10'	Partial blocking rotor	1h55
10/06/2025	06h55'	Partial disconnection terminal Y	3h40

II.2.2. Pareto diagram

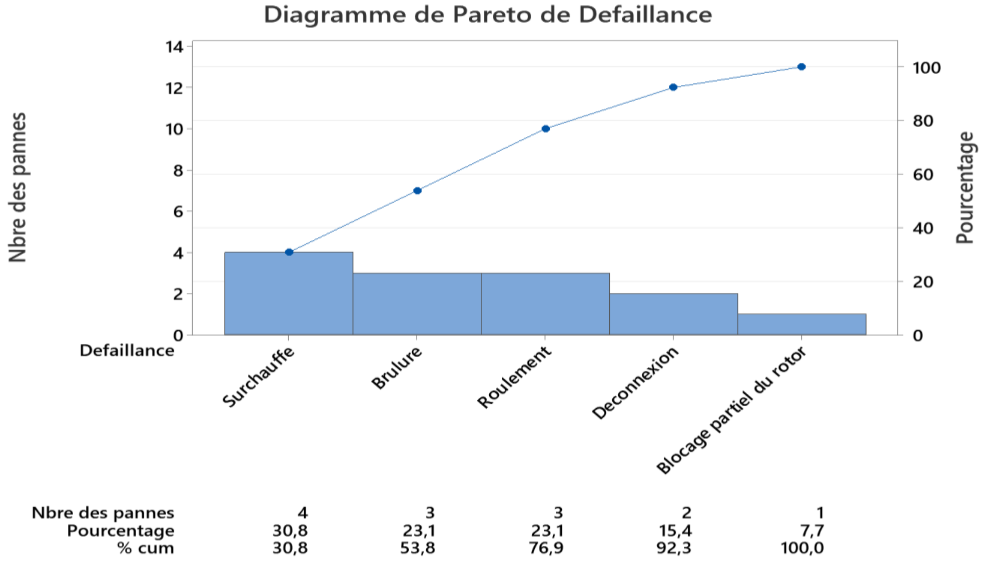

Figure 1: *Pareto diagram*

The Pareto diagram in figure 2 shows us that 76.9% of failures are mainly due to three causes: an abnormal increase in temperature with 30.8%, bearing wear and a burn-out with 23.1 each.

II.2.3. Causes and effects diagram

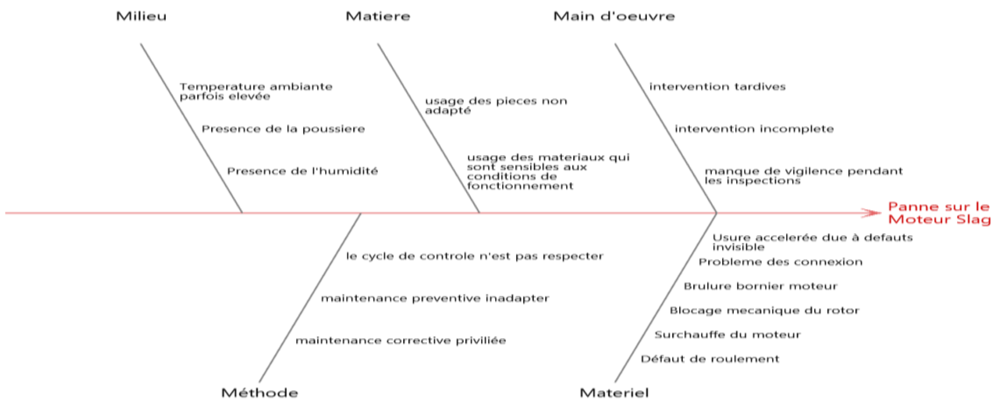

Figure 2: *ISHAKAWA diagram*

II.3. Realization

In this section, we will analyze the reliability, maintainability, and availability of the 132kW, 415V, tetrapolar, induction motor with a cage, 1450rpm.

II.3.1. Importance of the history for the 132kW asynchronous motor

The breakdown history is of paramount importance for the latter, as it provides information on the short working time "TBF" and the technical repair time "TTR".

II.3.2. Calculation of the TBF and TTR

From the breakdown history for the period from 01/28/2024 to 06/10/2025.

Formula (I) will allow us to determine the TBFs

$$TBF_i = (JBF \times 24) + (heures\ d'arret - heures\ de\ la\ remise\ precente) \qquad \textbf{(I)}$$

Table4 *: TBF and TTR table*

TBF	TTR
433,75	2,75
986	2
1059	3
1034,25	2,25
913,5	1,5
987,25	3,33
1681,16	1,17
410,66	2,67
1299,25	3,25
914,33	2,33
889,91	1,92
1395,66	3,67

The 132kW asynchronous motor (slag) required 29.84h of maintenance divided into 13 failures.

II.3.3. Determination of the Weibull distribution parameters

The determination of the Weibull parameters will allow us to determine the following parameters:

- β: shape parameter
- η: scale parameter
- γ: position parameter

Based on the table of good operation time of the asynchronous motor, our sample is N=12. To determine the frequency of damage, we will use the median-rank formula (II):

$$F_i = \frac{i-0,3}{N+0,4} \qquad \textbf{(II)}$$

Table5 : TBF Table

Order of i	TBF(time)	Fi	Fi en %
1	410,66	0,05645161	5,6451613
2	433,75	0,13709677	13,709677
3	913,5	0,21774194	21,774194
4	914,33	0,2983871	29,83871
5	889,91	0,37903226	37,903226
6	986	0,45967742	45,967742
7	987,25	0,54032258	54,032258
8	1059	0,62096774	62,096774
9	1034,25	0,7016129	70,16129
10	1299,25	0,78225806	78,225807
11	1395,66	0,86290323	86,290323
12	1681,16	0,94354839	94,354839

By introducing the time-to-run data into the Minitab software, we obtain the curve illustrated in Figure 4:

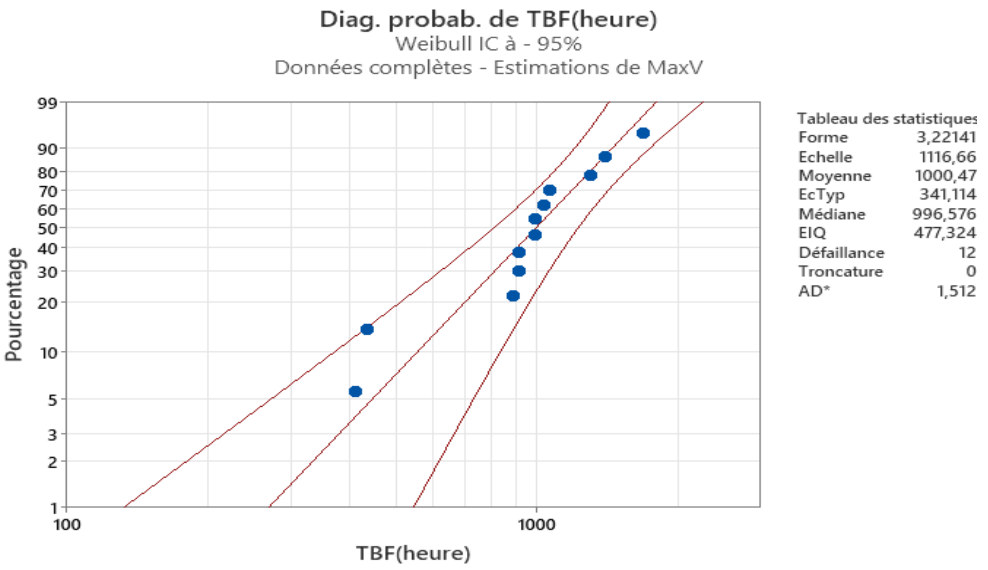

Figure 3 *Weibull paper*

From the Weibull curve, we can deduce the value of different parameters, of which the results are:

- Shape parameter $\beta = 3.22141$
- Scale parameter: $\eta = 1116.66$
- Position parameter (truncation): $\gamma = 0$

II.3.3. Calculation of the MTBF and MTTR

For the determination of the mean time of good MTBF operation and the technical mean time of MTTR repair, we will first determine the normalized value of the form factor β in the table of Johnson parameters, from which we will deduce the value of A and B.

Table6 *: Numerical tables for a Weibull law (Johnson table) [10]*

B	A	β	A	B	β	A	B
0,2	120	1,65	0,8942	0,556	4,2	0,9086	0,244
0,25	24	1,7	0,8922	0,54	4,3	0,9102	0,239
0,3	9,2625	1,75	0,8906	0,525	4,4	0,9146	0,235
0,35	5,291	1,8	0,8893	0,511	4,5	0,9125	0,23
0,4	3,3234	1,85	0,8882	0,498	4,6	0,9137	0,226
0,45	2,4686	1,9	0,8874	0,486	4,7	0,9149	0,222
0,5	2	1,95	0,8867	0,474	4,8	0,9116	0,218
0,55	1,7024	2	0,8862	0,463	4,9	0,9171	0,214
0,6	1,546	2,1	0,8857	0,443	5	0,9162	0,21
0,65	1,3663	2,2	0,8856	0,425	5,1	0,9192	0,207
0,7	1,2638	2,3	0,8859	0,409	5,2	0,9202	0,203
0,75	1,1906	2,4	0,8865	0,393	5,3	0,9213	0,2
0,8	1,133	2,5	0,8873	0,38	5,4	0,9222	0,197
0,85	1,088	2,6	0,8882	0,367	5,5	0,9232	0,194
0,9	1,0522	2,7	0,8893	0,355	5,6	0,9241	0,191
0,95	1,0234	2,8	0,8905	0,344	5,7	0,9251	0,186
1	1	2,9	0,8919	0,334	5,8	0,9226	0,165
1,05	0,9803	3	0,893	0,325	5,9	0,9269	0,183
1,1	0,9649	3,1	0,8943	0,316	6	0,9277	0,18
1,15	0,9517	**3,2**	**0,8957**	**0,307**	6,1	0,9266	0,177
1,2	0,9407	3,3	0,897	0,299	6,2	0,9294	0,175

1,25	0,99314	3,4	0,8984	0,292	6,3	0,9302	0,172
1,3	0,9236	3,5	0,8997	0,285	6,4	0,9331	0,17
1,35	0,917	3,6	0,9011	0,278	6,45	0,9313	0,168
1,4	0,9114	3,7	0,9025	0,272	6,5	0,9316	0,167
1,45	0,9067	3,8	0,9083	0,266	6,6	0,9325	0,166
1,5	0,9027	3,9	0,9051	0,26	6,7	0,9335	0,163
1,55	0,8994	4	0,9064	0,254	6,8	0,9334	0,161
1,6	0,8942	4,1	0,9077	0,249	6,9	0,9347	0,15

The parameters of the weibull previously obtained in the Minitab software, The normalized value of β is 3.2; which allows us to deduce the value of A and B respectively 0.8957 and 0.307.

II.3.3.1. Calculation of the MTBF

To determine the MTBF, we will do the product of the value A and the shape parameter then add the value of the truncation (position parameter), the mathematical expression (III) allows us to find the MTBF:

$$= \eta + \gamma \qquad \text{(III)}$$

Digital application

A = 0.8957; η = 1111.66; γ = 0 ; B = 0.307

MTBF= 0.8957 1,116.66 + 0 = 1,000.192 hours

Furthermore, the standard deviation is determined by:

σ = η = 0.307 1116.66 = 342.814 hours

II.3.4. Calculation of the MTTR

To determine the MTTR, we will sum TTR on the number of repairs by formula (IV):

$$MTTR = \frac{\sum TTR}{N_{bre}\ de\ réparation} \qquad \textbf{(IV)}$$

Digital application

TTR = 2.75 + 2 + 3 + 2.25 + 1.5 + 3.33 + 1.17 + 2.67 + 3.25 + 2.33 + 1.92 + 3.67 = 29.89 h

Number repair = 12

$$MTTR = \frac{\sum TTR}{N_{bre}\ de\ réparation} = 2{,}487\ heures$$

The repair of the asynchronous motor slag, lasts on average 2,487 hours.

II.3.5. Calculation of the reliability, probity density, and failure rate associated with the MTBF

From the MTBF, we will determine the reliability, the probability density as well as **the failure rate of the asynchronous motor slag:**

II.3.5.1. Failure rate calculation

The failure rate or damage rate is noted λ (t) or Z(t) represents the probability of failure at t + t of an equipment or subset of an equipment. [5] We will determine $\lambda(t)$ by the formula (V):

$$\lambda(t = MTBF) = \frac{\beta}{\eta} \times \left(\frac{t-\gamma}{\eta}\right)^{\beta-1} \qquad \textbf{(V)}$$

Digital application:

η= 1 111.66 hours; β = 3.2; γ =0 ; t=MTBF= 1,000.192 hours

$$\lambda(t = 1\,000{,}192) = \frac{3{,}1}{1\,111{,}66} \times \left(\frac{1000{,}192}{1\,111{,}66}\right)^{2{,}2} = 0{,}0022\ heures$$
$$\lambda(t = 1\,000{,}192) = 0{,}22\%$$
The failure rate for the slag engine is 0.22%.

II.3.5.2. Calculation of the reliability associated with MTBF

Reliability is defined as the ability of an entity to perform a required function, under given conditions, during a given time interval. [2], it will be determined by the relation (VI):

$$R(t = MTBF) = e^{-\left(\frac{t-1}{\eta}\right)^{\beta}} \quad \textbf{(VI)}$$

Digital application:

η= 1 111.66 hours; t= 1,000.192 hours

$$R(t = 1\,000{,}192) = e^{-\left(\frac{1000{,}192}{1111{,}66}\right)^{3{,}2}} = 0{,}49$$
$$R(t = 1000{,}192) = 49\%$$
The reliability of the asynchronous motor slag is low, it is 49%.

II.3.5.3. Calculation of the probability density associated with MTBF

Is the probability of occurrence of a circumstance in time. We determine it by the product of the failure rate and reliability, mathematically it is translated by the relation (VII):

$$f(t = MTBF) = \lambda(t = MTBF) \times R(t = MTBF) \quad \textbf{(VII)}$$

$$f(t = 1000{,}192) = 0{,}0022 \times 0{,}49 = 0{,}001078$$
The probability density is 0.107%

II.3.5.4. Calculation of the allocation function associated with MTBF

The distribution faction indicates the probability with which the 132kW asynchronous motor is likely to encounter a failure over time t.

It is determined by the following formula (VIII):

$$F(t = MTBF) = 1 - R(t = MTBF) \quad \textbf{(VIII)}$$
$$F(t = 1000{,}192) = 1 - 0{,}49 = 0{,}51$$
$$F(t = 1000{,}192) = 51\%$$
The distribution function is 51%. This means that the engine has a 51% chance of failing before time t.

II.3.5.5. Maintainability associated with MTBF

Maintainability is the probability that the equipment will be repairable before time. It is determined by the expression (IX):

$$M(t = MTBF) = 1 - e^{-\mu t} \quad \textbf{(IX)}$$
Withμ, the repair rate, it is determined by the relationship (X) :

$$\mu = \frac{1}{MTTR} \quad \textbf{(X)}$$
Digital application:

$\mu = \frac{1}{2{,}487} = 0{,}402$ Intervention/hour

Maintainability is then determined by:

$$M(t = 2{,}487) = 1 - e^{-(0{,}402 \times 2{,}487)} = 0{,}632$$
The slag editor is maintainable at 63.2%.

II.3.5.6. La disponibilité du moteur asynchrone slag
II.3.5.6. Availability of the slag asynchronous motor

Availability is the ability of an asset to be in a state to perform a required function under given conditions, at a given time or during a given interval of time.

It is defined by relation (XII):

$$\text{(XII)} D = \frac{MTBF}{MTBF+MTTR}$$

Digital application

$$D = \frac{1000{,}192}{1000{,}192 + 2{,}487} = 0{,}9975$$

The engine is capable of functioning correctly 99.75% of the time. This means that within the 1000h MTBF, the engine operates without failure for 997.75 hours, and repairs take an average of 0.25%, or 2.5 hours.

II.3.6. Reliability curve, failure rate and associated distribution function for TBFs

II.3.7.1. Reliability curve as a function of TBF

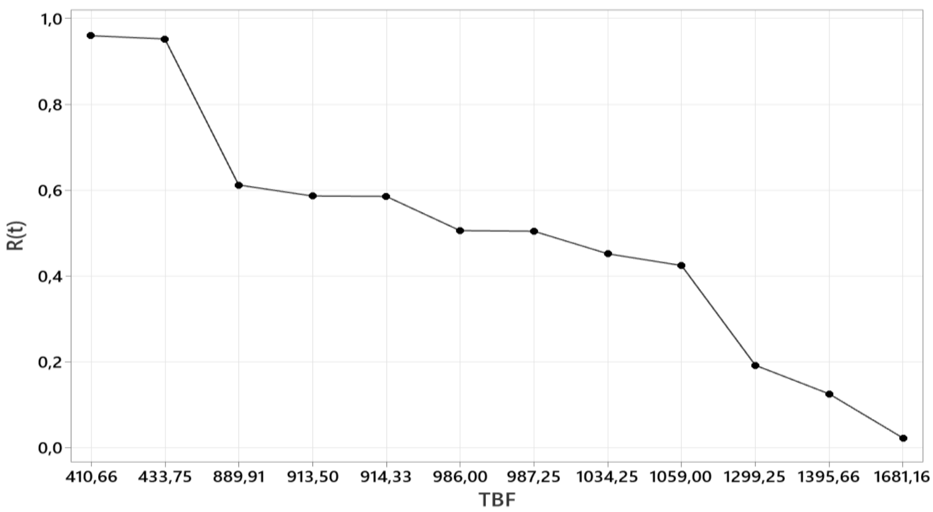

Figure4*Reliability curve as a function of each TBF*

The downward slope of the reliability curve indicates a gradual decline in equipment performance. This means that, over time, the equipment's ability to perform its designed function decreases, reflecting an increased risk of failure.

II.3.6.2. Failure rate curve as a function of TBF

Figure 6 provides important information regarding the 132 kW asynchronous motor. We observe that the failure rate curve increases progressively over time, confirming that the motor is currently operating in its aging phase. This observation is consistent with the value of the shape parameter $\beta=3.2>1$ found in the Weibull paper.

II.3.6.3. Distribution function curve

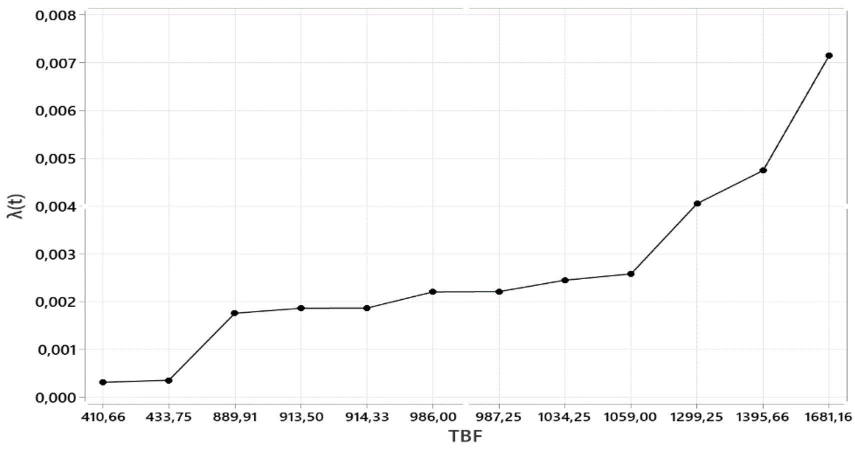

Figure5Shape of the failure rate curve

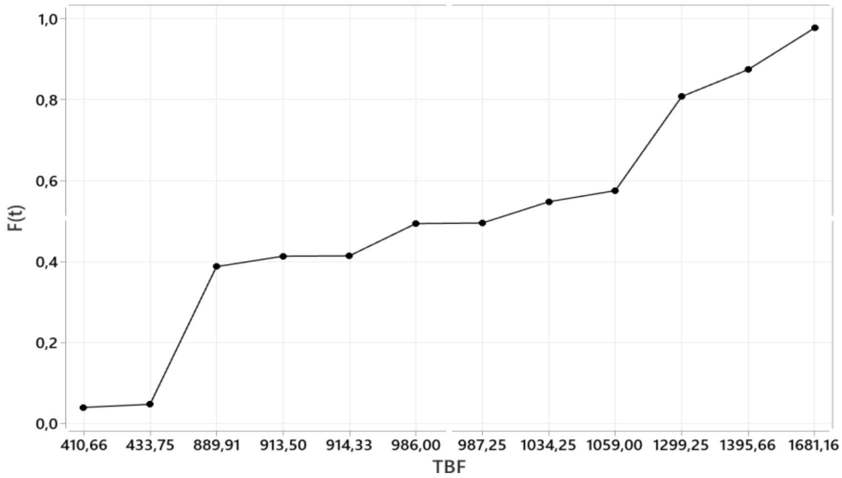

Figure6 Distribution function curve as a function of TBF

Upon observation of this curve, we note that the distribution functionF(t)tends to gradually approach 1 as timetadvance. This reflects a growing accumulation of failures over time. In other words, asF(t)As the load increases, the 132 kW asynchronous motor becomes increasingly susceptible to failure. This trend highlights the natural progression of aging and wear of the equipment, and justifies the need for continuous monitoring and the implementation of appropriate preventive maintenance.

II.3.6.4. Duality between the reliability curve and the distribution function

On the graph, the red curve represents the reliability R(t), which decreases over time, while the blue curve represents the cumulative distribution function F(t), which increases accordingly. We observe that the reliability curve intersects with the cumulative distribution function curve at the first operating time (TOT) of 986 hours, then continues up to the first operating time (TOT), which is 987.25 hours. After this point, the reliability curve decreases and the cumulative distribution function curve increases, indicating that the failure occurs at time t = 986 hours. At time t = 987.25 hours, the engine begins to exhibit faults.

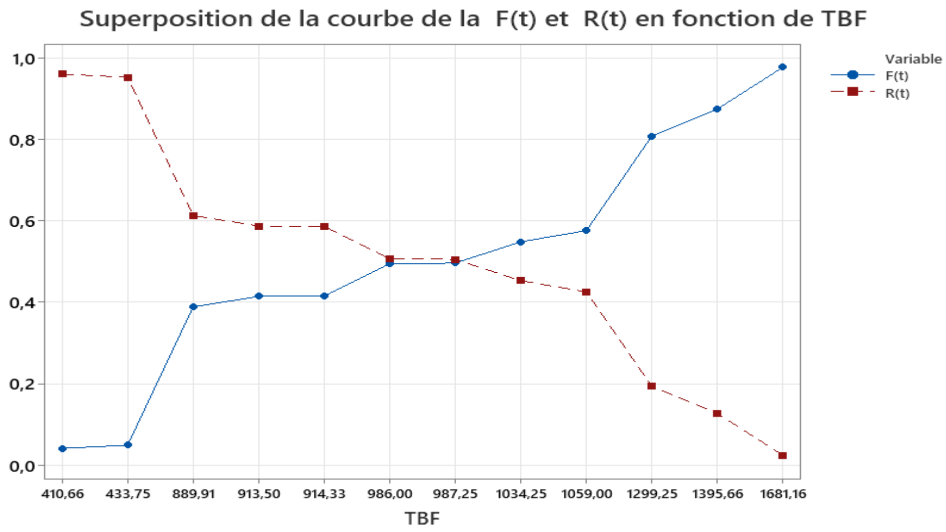

Figure7 *:Superposition of the curve F(t) and that of R(t)*

II.3.7. Implementation of a maintenance plan

In light of the results obtained by the statistical study, the following measures must be put in place:

1. **Monitoring of rolling stock status (Weekly)**

- Vibration control
- Bearing temperature control.

2. **Thermal inspection of the terminal block (Weekly)**

- Visual inspection to detect improper tightening or burning.
- Temperature control.

3. **Visits (monthly)**

- Bearing lubrication control.
- Mechanical coupling check.
- Checking electrical connections.

II.4. Presentation of results

Statistical analysis of RUBAMIN's data on the 132 kW (Slag) engine reveals a critical degradation in performance indicators. Based on a sample of thirteen major failures, the conclusions are as follows:

- **Life cycle assessment:**The Weibull shape parameter β = 3.2$ confirms that the equipment has left its maturity phase to enter a phase of accelerated aging or wear.
- **Reliability Index:**The probability of proper functioning is now only 49%, giving way to a dominant probability of failure of 51%.
- **Performance gap (MTBF):**The Mean Time Between Failures (MTBF) collapsed, falling from the originally planned 4,000 hours to approximately 1,000 hours, representing a fourfold reduction in initial productivity.

II.5. Analysis and discussion

The 132 kW asynchronous motor (slag), initially designed for 4,000 hours of continuous operation, has seen its average uptime reduced by a factor of four since its commissioning, representing a significant blow to productivity. Calculations demonstrate that this motor has low reliability, on the order of 49%. Thus, instead of its theoretical 4,000 hours of continuous operation, the motor is currently operating, according to previous data, for only [number of] hours on average. Furthermore, Weibull analysis shows that the motor is now in its advanced aging or wear phase, as clearly illustrated by the estimated form parameter of 3.2.1000,192

II.5.2. Discussion

After analysis, we have determined that the current maintenance practices are no longer reliable, as confirmed by the reliability curve showing a significant decline characterized by repeated downtime. We therefore suggest implementing condition-based preventive maintenance, which should focus on the operating condition of the equipment to ensure continuous production.

The current maintenance strategy, primarily reactive, is proving ineffective in the face of declining reliability. Maintaining this approach condemns the company to repeated downtime and high corrective costs.

We recommend a shift towards condition-based preventive maintenance:

- **Intervention threshold:**A systematic review must be triggered as soon as the threshold of 1,000 hours of operation is reached.
- **Focal point:**Absolute priority is given to vibration and thermal diagnosis of bearings, the starting points of chain failures.

No	Equipment	Quantity	Unit cost	Total cost (USD)
1	SKF 6319 Ball Bearing	3	25	75
2	Terminal plate	3	15	45
3	Total Lubricant 5L	1	21	21
4	Unforeseen			14
TOTAL				155
Workforce				42
TOTAL ESTIMATED COST				197

Stop date	stop time	Cause or malfunctions	Intervention time	Submission date	Delivery time
28/01/2024	08:45	Bearing defect.	2h30'	28/01/2024	11:15
15/02/2024	10:20	Burning of the terminal block (phase R).	1 hour 45 minutes	15/02/2024	12:05
27/03/2024	1:10 PM	General abnormal overheating	2:00	27/03/2024	3:10 PM
10/05/2024	9:30 AM	Rear bearing defect.	3:00	10/05/2024	12:30
22/06/2024	2:50 PM	Neutral terminal burn	2h15'	22/06/2024	5:05 PM
30/07/2024	07:15	Overheating after prolonged start-up.	1 hour 30 minutes	30/07/2024	8:45
09/09/2024	4:05 PM	Accelerated wear of the front/rear bearing	3h20'	09/09/2024	7:20 PM
18/11/2024	11:40	Intermittent overheating.	1 hour 10 minutes	18/11/2024	12:50
05/12/2024	3:25 PM	Cable disconnection + burn	2h40'	05/12/2024	6:05 PM
28/01/2025	1:10 PM	Scratching noise ► sudden stop	3:15	28/01/2025	4:25 PM
07/03/2025	11:25	Prolonged	2h20'	07/03/2025	1:45 PM

		overheating			
13/04/2025	4:10 PM	Partial rotor lock	1 hour 55 minutes	13/04/2025	6:05 PM
10/06/2025	06:55	Partial disconnection of terminal Y	3:40	10/06/2025	10:35

Painting7Table 6: Failure History Table

$$R(t) = e^{-\left(\frac{t}{1111,66}\right)^{3,2}}$$

$$\lambda(t) = \frac{3.1}{1111,66} \times \left(\frac{t}{1111,66}\right)^{2,2}$$

$$F(t) = 1 - e^{-\left(\frac{t}{1111,66}\right)^{3,2}}$$

$$f(t) = \frac{3.1}{1111,66} \times \left(\frac{t}{1111,66}\right)^{2,2} \times e^{-\left(\frac{t}{1111,66}\right)^{3,2}}$$

Painting8*Table of R(t) of*

TBF (hours)	R(t)
410.66	0.95953362
433.75	0.95198091
889.91	0.61221079
913.5	0.58653216
914.33	0.58562211
986	0.50599263
987.25	0.50459424
1034.25	0.45213976
1059	0.42478864
1299.25	0.19261758
1395.66	0.12605702
1681.16	0.0233542

Painting9*Failure rate table based on TBF*

TBF	λ(t)
410.66	0.00032189
433.75	0.00036305
889.91	0.00176442
913.5	0.00186895
914.33	0.00187269
986	0.0022109
987.25	0.00221707
1034.25	0.00245593
1059	0.00258709
1299.25	0.00405661
1395.66	0.00474848
1681.16	0.00715121

Painting10Table of F(t) as a function of TBF

TBF	F(t)
410.66	0.04046638
433.75	0.04801909
889.91	0.38778921
913.5	0.41346784
914.33	0.41437789
986	0.49400737
987.25	0.49540576
1034.25	0.54786024
1059	0.57521136
1299.25	0.80738242
1395.66	0.87394298
1681.16	0.97664578

Painting11Table of f(t) as a function of

TBF	f(t)
410.66	0.00030886
433.75	0.00034562
986	0.00108019
889.91	0.0010962
1059	0.00109669
1034.25	0.0011187
913.5	0.00111872
1681.16	0.00111042
1299.25	0.00109896
914.33	0.00078138
1395.66	0.00059858
987.25	0.00016701

Painting12*Table for determining the Pareto Diagram*

Ranking	Failure	Number of breakdowns	cumulative percentage of breakdowns	% cumulative
1	Bearing	3	23.1%	23.1%
2	Overheated	4	30.8%	53.8%
3	Burn	3	23.1%	76.9%
4	Logout	2	15.4%	92.3%
5	Partial rotor lock	1	7.7%	100.0%

II.7. Difficulty encountered

During our fieldwork, we encountered two major difficulties: the unavailability of technical datasheets for the asynchronous motors and the absence of records for certain motors. To overcome these obstacles and achieve our objective, we consulted the technical datasheets on the manufacturer's official website. This website is an essential resource, containing all the key information about Rubamin's asynchronous motors.

General Conclusion

This study, dedicated to the diagnosis and optimization of asynchronous motor maintenance at RUBAMIN, reveals that equipment reliability is directly correlated with the severity of its operating environment. The in-depth analysis of the 132 kW "Slag" motor, conducted between January 28, 2024, and June 10, 2025, confirmed the predominant impact of industrial dust and thermal stress (50°C) on the development of failures.

Applying Weibull's probability distribution to the history of the thirteen recorded breakdowns provided irrefutable quantitative evidence:

- A degradation of the life cycle:The shape parameter β = 3.2 demonstrates that the engine has left its mature phase and entered a phase of accelerated wear.
- A collapse in reliability:The mean time between failures (MTBF) observed is 1,000 hours, which is only a quarter of the theoretical lifespan of 4,000 hours initially planned.
- A critical performance diagnosis:With a reliability rating of only 49%, the engine has a 51% probability of failure at any given time, making production unstable.

The main lesson from this project is the inadequacy of the current maintenance strategy in the face of real-world conditions. While equipment redundancy ensures relative continuity, it does not address the root causes (bearing wear and winding overheating).

In conclusion, it is imperative for RUBAMIN to abandon purely corrective or systematic maintenance in favor of condition-based preventive maintenance. Implementing continuous monitoring, based on vibration and thermographic analysis, would allow for the detection of early warning signs of failure as early as the critical 1,000-hour threshold. This proactive approach is the only way to guarantee the longevity of equipment, optimize its availability, and ultimately stabilize the company's annual performance.

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