

Development of computational tool for determination of reliability exactitude of industrial equipments using WEIBULL MODEL

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Abstract

Our work is devoted to the theoretical and practical study of the industrial reliability based on the experience feedback and the reliability models.

In this paper we cite the «Weibull model» to predict the reliability of equipment at any period of its life time (burn-in, useful life and wear-out period), used for assessing failure rate, therefore, the orientation in selecting a proper maintenance policy, comparing to classical probability laws that are limited.

Finally, we finalized our work by the conception of a computer application for SONATRACH, programmed using MATLAB language, applied for any machines (mechanical, electrical and electronic equipments).

Keywords : reliability, Weibull, maintenance, MTBF, MATLAB.

1. INTRODUCTION

Throughout history, Mankind has always wanted to build reliable things, but the mathematical tools to quantify this reliability have not been developed until recently. The first industrial areas where it appeared were large military systems, space, nuclear and automotive industry and finally, capital goods. One can quote that in 1906 American manufacturers of electronic empty tubes were concerned for their reliability. At the same time, the first studies on the ball bearings appeared. Then later, Waloddi Weibull proposed his famous model in 1937. He wrote an article on this subject in 1951 and US forces recognized his merit in 1975. It predicts his model a great success, which was confirmed later.

After WWII, the US Department of Defense initiated the development of reliability studies on electronic tubes. In 1961, Bell Telephone developed the Fault Tree Analysis while the group AGREE (Advising Group on reliability of

electronic equipment) was working on electronic equipment reliability. Reliability by software was born later around the 1980s.

It should also be noted that there are several events in the field of mechanical engineering that devotes a section to the reliability. This reliability is defined by the engineer as the ability of a device to perform a required function under given condition and for a specific time period. On the other hand, the mathematician transforms this definition speaking of the probability of performing a required function.

Some work on reliability have been developed using mainly the exponential law for applications in the field of maintenance as the work of Zwinglestein G. in 1996 "maintenance based on reliability, practical guide for the RCM". The latter was born in the aviation sector in the late 1960s with large aircraft. Standardized as «RCM» (reliability centered maintenance), it is now used by all airlines and other industries seeking for competitiveness. The author points out the importance of the roles of functional analysis and feedback of experience.

Therefore, the study of reliability is applied to all equipment in several industrial areas in general and in the oil sector in particular (gas turbines, pumps, compressors, electric motors, static equipment, etc. ...).

The topic we are interested in «Reliability of the 34"/OK1/HEH Turbopump TP6 (GE MS3002 Gas Turbine and Bayron-JACKSON Pump)» consists on the determination of the reliability parameters using the Weibull model of the turbo pump that ensures the pumping of crude oil from Haoud El Hamra to Skikda for refinery and for export at a rate of up to 5000m³/h. The parameters of «Weibull» are, in first approach, determined by graphical methods (use of «Allen Plait» paper) and then, more precisely, by the analytical method of least squares, using a numerical program language «MATLAB».

The Weibull model is a general model that can be applied to any device (mechanical, electrical and electronics) and in all its life phases (burn-in, useful life, wear-out, where the failure rate is variable) comparing to other models such as the exponential law, which is a special case of «Weibull» model, the normal law and the Poisson distribution. The model of «Weibull» is a very important tool that allows us to create a computer application (using the MATLAB programming language) which will benefit SONATRACH. This application has as input the uptime (TBF) from the historical record of equipment and outputs the parameters of «Weibull» and the current reliability of the equipment.

The works of Patrick Lyonnet and his book «Ingénierie de la fiabilité» appeared in 2006, he reported on components and systems reliability techniques (Mechanical, electromechanical, computer) and their implementation in the industrial process. The various forms of reliability are developed: forecast, operational and experimental, as well as their suitability to the various cases encountered[1].

The works of Jean Bufferne, entitled «Fiabilisation des équipements» (2008). It offers in an accessible way this essential mathematical tool (reliability) to disposal of those who participate in the development of maintenance policies. This work is in the field of industrial maintenance, and it treats the essential basics of reliability. The author has dealt with a practical case of the determination of reliability parameters of the punch machine shaft using the model of «Weibull» ($\gamma = 0$) and at the same time he used maintenance costs for the determination of the systematic replacement period [2].

The doctoral thesis work of Tebbi Ouahiba (2005) on the topic «Estimation des lois de fiabilité en mécanique par des essais accélérés» In this work, she estimated the reliability of systems subject to mechanical damage under normal conditions of use and for the first time she demonstrated SVA models (standard de vie accéléré) with real data of experimental designs in the mechanical field [3]. The works of Mathieu Glade (2005) on the topic «La modélisation des coûts de cycle de vie : prévision des coûts de maintenance et la fiabilité. Application à l'aéronautique» the author treats the modeling of helicopter mechanical components using the neural network method[4].

2.GENERAL NOTES ON RELIABILITY

In this section, we will present some laws of distributions involved in the analysis of life data used in a reliability study.

We quote the main properties of these laws (density, function reliability and failure rate) and their application in reliability.

This section will also provide an understanding of life data analysis, Weibull and Log-Normal analysis will be emphasized particularly for failure analysis.

2.1.Definitions and understanding the reliability parameters

2.1.1. Reliability R(t) : The probability that an item will perform its stated function satisfactorily for the desired period when used per the specified conditions [5].

2.1.2. MTBF : is the predicted elapsed time between inherent failures of a system during operation[6].

2.1.3. Failure rate(t) : is the frequency with which an engineered system or component fails, expressed in failures per unit of time. It is often denoted by the Greek letter λ (lambda) and is highly used in reliability engineering [7]. It is defined by the following equation :

$$\lambda(t) = \frac{f(t)}{R(t)} \quad (1)$$

Where

$f(t)$: Probability density function;
 $R(t)$: Reliability function.

2.1.4. The bathtub curve : The bathtub curve seeks to describe the variation of failure rate of components during their life. The failures exhibited in the first part of the curve, where failure rate is decreasing, are called early failures or infant mortality failures. The middle portion is referred to as the useful life and it is assumed that failures exhibit a constant failure rate, that is to say they occur at random. The latter part of the curve describes the wearout failures and it is assumed that failure rate increases as the wearout mechanisms accelerate.

2.2. Some probability distributions of continuous random variables involved in industry

2.2.1. Exponential law : This is one of the most widely used probability distributions in engineering, particularly in reliability work [8]. It is relatively easy to handle in conducting analysis. This law has many applications in various fields. It is a simple law, widely used in reliability that the failure rate is constant. It describes the life of materials that undergo brutal failures as electrical and electronic equipments. Its functions are given by the following expressions :

- Reliability function: $R(t)=e^{-\lambda t}$ (2)
- Probability density function : $f(t)=\lambda e^{-\lambda t}$ (3)
- Expected value: $E(t)= MTBF=1 / \lambda$ (4)
- Standard deviation: $\sigma=1 / \lambda$ (5)

2.2.2. Normal distribution : This distribution is sometimes called the Gaussian distribution after Carl Friedrich Gauss (1777–1855), a German mathematician. It is one of the most widely used statistical distributions[9]. It is used to present the distribution of lifetimes of devices in their wear-out period because the failure rate is increasing.

The distribution probability density function is expressed by :

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(t-\mu)^2}{2\sigma^2}\right] \quad -\infty < t < +\infty \quad (6)$$

Where μ and σ are the distribution parameters (i.e. mean and standard deviation, respectively)

The failure function is given :

$$F(t) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^t \exp\left[-\frac{(t-\mu)^2}{2\sigma^2}\right] dy \quad (7)$$

This distribution was actually discovered by De Moivre as early as in 1733 but due to historical error was attributed to Carl Gauss.

2.2.3. Weibull distribution : This distribution was developed by W. Weibull of the Royal Institute of Technology, Stockholm, in the early 1950s [10]. Weibull distribution is useful for representing many different physical phenomena. It is one the most used distribution for its utilization in all the lifetime of a component (i.e. variable failure rate), for example: mechanical, electrical and electronic equipments.

Its probability density function is defined by :

$$f(t) = \left(\frac{\beta}{\eta}\right) * \left(\frac{t-\gamma}{\eta}\right)^{(\beta-1)} * e^{-\left(\frac{t-\gamma}{\eta}\right)^\beta} \quad (8)$$

Where β, η and γ are the shape, scale and location parameters, respectively.

The failure function is given :

$$F(t) = 1 - e^{-\left(\frac{t-\gamma}{\eta}\right)^\beta} \quad (9)$$

The primary advantage of the Weibull analysis is the ability to provide reasonably accurate failure analysis and failure forecasts with extremely small samples.

Another advantage of Weibull analysis is that it

provides a simple and useful graphical plot of the failure data [11].

a- Weibull's shape parameter signification

The slope of the Weibull plot, Beta, ($\beta > 0$), determines which member of the family of Weibull failure distributions best fits or describes the data. The slope, β , also indicates which class of failures is present:

- $\beta < 1$ indicates infant mortality;
- $\beta = 1$ means random failures (independent of age);
- $\beta > 1$ indicates wear out failures [9].

3. WEIBULL MODEL APPLICATION FOR RELIABILITY CALCULATION

The exponential distribution is a simple law applied in the domain of useful life or maturity period. It is characterized by a constant failure rate ($\lambda = \text{constant}$) which is the case of electrical or electronic equipment. Moreover, Laplace-Gauss law is widespread ; it is applicable in the case of the end of life (Wear-out) where the failure rate is still increasing.

In addition, the Weibull model is a flexible law that can fit a large number of samples collected along the life of the equipment. It covers the case of variable failure rate decreasing (Infant mortality) or growing (Wear-out). This law is widely used in reliability, especially in the mechanical field.

In our study we will adopt the Weibull model given its flexibility, its broad field of application in the bathtub curve and its capacity to encompass all the other laws that are special cases of the Weibull law.

Hence, this paper treats a practical case, using this tool, of a turbopump located in the transport activity (region of Hassi Messaoud) which is the 34"/OK1/HEH TP6. After that, In order to make the use of the Weibull model easy to manipulate, in the industry particularly for Sonatrach, we opted for the conception of a computed application based on MATLAB programming language that will provide:

- The Weibull parameters;
- The MTBF;
- The actual reliability of the equipment;
- Check the chi-squared test;
- Check the Kolmogorov-Smirnov test.

3.1. Functional division of the turbopump

The turbopump system is composed of a GE MS3002 turbine coupled with a Bayron-Jackson pump which ensures the oil pumping from 07 to 47 kg/cm².

As to the turbine, it is composed of an axial compressor which ensures suction and increase in flow rate and pressure of the ambient air. The latter is then fed to the combustion chambers where it is mixed with a fuel to provide heat energy. After this, compressed and burnt air-fuel mixture is expanded in the HP and LP turbine section to provide mechanical energy to the pump.

3.2. Application

In this part we will use the equipment operating results to actually apply the theory already mentioned before, especially that of reliability.

The data for this application are identified from historical records of each piece of equipment. Our choice fell on the turbine and the pump because its historical records have been kept updated since 1987.

NOTA : given the lack of Life Data, we will proceed to the study of the reliability of the entire turbine and pump as a sub-system and not in simple elements i.e. axial compressor, combustion chambers, HP and LP turbine, the pump rotor, bearings, mechanical seals etc...

3.2.1. GE MS3002 gas turbine reliability

Table 1 gives the TBF ranked in ascending order

TABLE 1 : Statistical data of proper functioning time (TBF) of the GE MS3002 turbine from 1989 to 2014

There are two methods for determining the parameters of Weibull: graphical and analytical method :

a- Graphical method

The calculation of the reliability parameters depends primarily on the fraction (estimated distribution function) defined by the equation :

$$F_{est}(t) = \frac{i}{n} \tag{10}$$

Where «n» defines the sample size and «i» defines the rank of the faulty component; ($50 \leq n$).

After this, we plot the scatter plots (Ti, Fi) on the paper of «WEIBULL» or «ALLAN PLAIT».

Determining the β, η and γ parameters

Since we have a complete Life Data for both the gas turbine and the pump from the commissioning of the machine (1989) so in this case we conclude that the location parameter Gamma ($\gamma=0$).

If a group of failures is distributed according to the Weibull function and it is initially assumed that

$\gamma=0$, then by plotting these failures against time on double logarithmic paper (failure percentage on log-log scale and time on log scale) a straight line should be obtained. The three Weibull parameters and hence the expression for Reliability may then be obtained from measurements of the slope and intercept.

The scatter plot, as it is shown in Figure.1, is connected by the D1 straight line whose intersection with the line Eta gives the value of the scale parameter (η). The translation of the D1 up to the origin O of the coordinate system (x, y) gives the straight line D2 whose intersection with the line Beta is used to read the value of the shape parameter (β).

Fig1. Plotting manually on the paper of ALLAN PLAIT

b- Analytical method using the least-squares fit

The following equations show how data which can be described by a Weibull function can be made to fit a straight line [9].

The Weibull expression can be reduced to a straight-line equation by taking logarithms twice:

If $F(t) = 1 - R(t)$ (11)

Then $1 - F(t) = \exp \left[- \left(\frac{t - \gamma}{\eta} \right)^\beta \right]$ (12)

So that $\frac{1}{1 - F(t)} = \exp \left(\frac{t - \gamma}{\eta} \right)^\beta$ (13)

Therefore $\log \left(\frac{1}{1 - F(t)} \right) = \left(\frac{t - \gamma}{\eta} \right)^\beta$ (14)

And $\log \left(\log \left(\frac{1}{1 - F(t)} \right) \right) = \beta \log(t - \gamma) - \beta \log(\eta)$ (15)

Which is equivalent to $Y = a \cdot X + b$, the equation of a straight line.

There are several numerical methods to linearize this equation $R(t) = 1 - F_{est}(t)$ for instance the method of Newton, Lagrange and the least squares fit.

Least-squares fit [11, 12]

Assume given the following points: (x1, y1)..... (xn, yn), we want to adjust these points with a right (D) «y» ~ «ax + b» to data is also known as linear regression. In this case the function to be minimized is A=

$$\sum_{i=1}^n e_i^2 \text{ and } e_i = y_i - \hat{y}_i = y_i - (ax_i + b)$$

$$\frac{\partial A}{\partial a} = 0 \Rightarrow a = \frac{\sum_{i=1}^n y_i (x_i - \bar{x})}{\sum_{i=1}^n x_i (x_i - \bar{x})} \quad (16)$$

$$\frac{\partial A}{\partial b} = 0 \Rightarrow b = \bar{y} - a\bar{x} \quad (17)$$

By analogy to (equation 15) we find $a=\beta$ and

$$\eta = \exp\left(-\frac{b}{a}\right)$$

To determine the reliability parameters from the equations of Beta and Eta and by using the «MATLAB» program, after calculation we find $\beta=0.86$ and $\eta=1981.5$ hours

The reliability law of the studied sample is given by the equation :

$$R(t) = \exp\left(-\left(\frac{t}{\eta}\right)^\beta\right) \text{ Et } \lambda(t) = \left(\frac{\beta}{\eta}\right)\left(\frac{t}{\eta}\right)^{\beta-1}$$

So

$$R(t) = \exp\left(-\left(\frac{t}{1981.5}\right)^{0.86}\right)$$

Fig2. Theoretical and Practical Failure Distribution and Interpolation of the failure function of the GE MS3002 gas turbine

- Calculation of the MTBF

The calculation of the MTBF is as follows :

$MTBF = x\eta + \gamma = 1.0522 * 2047 = 2153.71 \approx 2154$ hours or 89.75 days therefore almost 03 months, where x is given by a table depending on Beta(β)

$$R(MTBF) = e^{-\left(\frac{2154}{2047}\right)^{0.86}} = 0.35133$$

In this case we can say that we have 35% of chance that the turbine does not break down beyond the MTBF.

Or, that we have 65% of chance that the turbine fails beyond the MTBF.

c- Calculation of the Standard Deviation σ

The calculation of the Standard Deviation σ is as follows :

$\sigma = \eta\gamma = 1.1711 * 2047 = 2379.08 \approx 2379$ hours, where γ is given by a table depending on Beta (β).

Fig 3. Failure rate of the GE MS3002 turbine depending on time

- Applying correlation test

The Kolmogorov–Smirnov test

The Kolmogorov–Smirnov test (K–S test or KS test) is a nonparametric test that can be used to compare a sample with a reference probability distribution (one-sample K–S test). The Kolmogorov–Smirnov statistic quantifies a distance between the empirical distribution

function of the sample and the cumulative distribution function of the reference distribution [13].

The «Kolmogorov-Smirnov» test is checked at every point, so we can conclude that the theoretical law coincides with that of the sample, there is a risk of (1%) to be wrong between the two laws.

$$D_\alpha (\text{calculated}) = \max(|F_{theor} - F_{estim}|) < D_\alpha \quad (18)$$

The D_α value (0.223897719) is taken from a table depending on Beta (β) and an error risk α .

The Chi-square test

Pearson's chi-square test, also known as the chi-square goodness-of-fit test or chi-square test is a statistical test for independence. In order to determine a value of χ^2 it is necessary to specify two parameters. The first is the number of degrees of freedom and the second is the confidence level. The tables of χ^2 at the end of this paper have columns and rows labeled α and n . The confidence level of the χ^2 distribution is α or (p) and n or (ddl) is the number of degrees of freedom $n = k - r - 1$ [9].

$$\chi^2 = \sum_{i=1}^k \frac{(n_i - v_i)^2}{v_i} < \chi_{n,\alpha}^2 \quad (19)$$

With k number of classes and r number of parameters of statistical model used, for the:

- Weibull law $r=3$
- Exponential law $r=1$
- Normal law $r=2$

The chi-square test is a very important test that can predict if the equipment reliability is only due to the fluctuations of the sample (TBF) or not.

To verify this test we conduct a long sequence of calculus in order to determine theoretical effectiveness with then apply the compliance criteria (equation.19).

In our case, the test is checked for a confidence of 80%

3.2.1. BAYRON-JACKSON pump reliability

Table 2 gives the TBF ranked in ascending order

TABLE 2 : Statistical data of proper functioning time (TBF) of the BAYRON-JACKSON pump from 1989 to 2014

The calculation of the reliability parameters depends primarily on the fraction (estimated distribution function) defined by the equation :

$$F_{est}(t) = \frac{i}{n + 1} \quad (20 \leq n \leq 50) \quad (20)$$

To determine the set of parameters of the pump we use the same steps as for the gas turbine. The results are shown below :

$$\beta = 0.61$$

$$\eta = 3316 \text{ hours}$$

$$R(t) = e^{-(t/3316)^{0.61}}$$

$$\lambda(t) = 1.84 * 10^{-4} \left(\frac{t}{3316}\right)^{-0.39}$$

$$MTBF = 4990 \text{ hours}$$

$$R(MTBF) = e^{-(4990/3316)^{0.61}} = 0.27778$$

$$\sigma = 8772 \text{ hours}$$

The test of Kolmogorov-Smirnov is checked and the chi-square test is not applicable for small samples

Fig 4. Theoretical and Practical Failure Distribution and Interpolation of the failure function of the BAYRON-JACKSON pump

Fig 5. Failure rate of the BAYRON-JACKSON pump depending on time

3.2.3. The case where Gamma $\gamma \neq 0$

If the Life Data of the component is not taken from its commissioning date, in this case the location parameter $\gamma \neq 0$ (it rarely happens).

We use a method that allows us to obtain the value of Gamma when the scatter plot does not represent a straight line but a curve (concave or convex) then we determine the others parameters the same way as mentioned earlier for Gamma=0 [14].

To determine the value of Gamma, we should conduct a variables changing (t- γ); and we will get a straight line, so all the scatter plot is translated by a value of Gamma. We choose 3 equidistant points in the Y-axis a1, a2, a3. These points permit to obtain the correspondent TBF: t1, t2, t3

On the curve, we obtain the points :

$$M1 \left| \begin{matrix} \log(t_1) \\ Y_1 \end{matrix} \right., M2 \left| \begin{matrix} \log(t_2) \\ Y_2 \end{matrix} \right., M3 \left| \begin{matrix} \log(t_3) \\ Y_3 \end{matrix} \right.$$

After translating the entire scatter plot to a straight line, it allows us to write the following expression:

$$\frac{Y_3 - Y_2}{\log(t_3 - \gamma) - \log(t_2 - \gamma)} = \frac{Y_2 - Y_1}{\log(t_2 - \gamma) - \log(t_1 - \gamma)}$$

More we have

$$Y_3 - Y_2 = Y_2 - Y_1$$

So

$$\log(t_3 - \gamma) - \log(t_2 - \gamma) = \log(t_2 - \gamma) - \log(t_1 - \gamma)$$

$$\Rightarrow \frac{t_3 - \gamma}{t_2 - \gamma} = \frac{t_2 - \gamma}{t_1 - \gamma}$$

$$\Rightarrow (t_3 - \gamma)(t_1 - \gamma) = (t_2 - \gamma)^2$$

Finally we get the value of Gamma

$$\gamma = \frac{t_2^2 - t_1 * t_3}{2t_2 - t_1 - t_3} \quad (21)$$

4. WEIBULL'S MODEL APPLICATION ON THE GE MS3002 TURBINE USING MATLAB PROGRAMMING

The Weibull model is a general application for reliability calculation of any equipment at any period of its functioning. Thus, it is a useful tool for the determination of its actual reliability which is an important maintenance indicator along with maintainability and availability that allows the orientation of the maintenance policy of a company. So, we opted to convert the set of Weibull model calculus to an application using the language of MATLAB programming that can be used for the benefit of SONATRACH Company. It can be run on Windows and Linux and it does not require the installation of the MATLAB language.

After installing the application on Windows or Linux we run it as administrator, and a menu will appear :

Fig 6. The application's MENU

After that, we choose between two options offered by the application: "Maintenance of Machines" or "Energetic State of Gas Turbines or Turbopumps". In our case, we click on the first button and another window will open:

Fig 7. Two cases of Weibull model to apply ($\gamma=0$ and $\gamma \neq 0$)

We click on the first button when we have a complete Life Data ($\gamma=0$) i.e. the case where the data are taken from the commissioning of the component as in our case, then the second one is used when we have an incomplete Life Data ($\gamma \neq 0$).

The next pictures show the results of Weibull's application, created by MATLAB programming; using the data of the GE MS3002 turbine for example, we can also use the data of the BAYRON-JACKSON pump.

Fig 8. Interface and display N°01 of the results obtained from the Weibull model Application

Fig 9. Results of the Weibull model Application used on the GE MS3002 turbine case

Fig 10. Display N°02 of the results obtained from the Weibull model Application

This application that we have conceived using MATLAB programming can also be a tool for the simulation of the energetic state of any gas turbines or turbopumps.

Fig 11. The application's MENU

Clicking on the second button, a menu window will open :

Fig 12. The menu of the gas turbine thermodynamics simulation

After clicking on a button, for instance, 'Turbopump', the following pictures of the results of the gas turbine thermodynamics analysis application will be displayed:

Fig 13. Simulation of the turbopump's energetic state

The energetic state simulation of the gas turbines or turbopumps shows the influence of the variation of the ambient temperature in its performances like efficiency, the specific compressor work, the specific turbine work and the crude oil pumped flow instantaneously.

5. CONCLUSION & RECOMMANDATIONS

We can conclude throughout this work that the evaluation of the reliability of industrial equipment is essential for the optimization of their lifespan. Reliability is an indicator of maintenance, therefore, to ensure the good availability of an equipment it is necessary to increase its reliability (fewer failures possible) which also plays an important role on the production (ensuring good reliability = ensure good production quality). In our case, it means ensure continuous production 24/24 and 7/7. Stopping the equipment (turbopump ensuring crude oil pumping of a flow of 3400m³/h on average towards Skikda «the largest refinery in Africa» and export) is not tolerable given the huge losses that present stopping the production for even a short time.

In our work, we studied the main laws used in reliability as well as the different methods for determining reliability parameters that characterize the degree of failure and allow following the status of equipment and choosing the type of maintenance to be applied.

We also note that the calculation of the mechanical reliability depends on the following key factors:

1- The notion of constant failure rate does not exist; because the mechanical failure rate is a

nonlinear function of time in each phase of the life of the equipment.

2- The collection of reliability data is difficult: It depends essentially on the organization and management of maintenance.

The shape parameter of the turbine and the pump is below 1 (burn-in period). It can seem confusing considering the age of the turbopump since it has been commissioned in 1987 but it can be explained by:

- The maintenance policy of the company is a purely systematic preventive maintenance which makes the machine almost new after each overhaul (after 32000h);
- The Time Between Failures of the turbo pump (TBF) may not be accurate for :
 - Lack of spare parts;
 - Long overhaul (TTR): up to five months instead of around 30 days;
 - Periodicity of revision of the turbopump is not respected.

In terms of perspective, we recommend :

- To conduct a study to evaluate the opportunity of applying a conditional maintenance policy rather than a systematic maintenance to turbines, since this has proven to be effective in other major oil companies.

- Apply a maintenance strategy to achieve the objectives set by the company that are related to the objectives of maintenance.

- The application of the maintenance operations on all of the equipment must be done by the team from HEH to minimize the machine downtime due to non-compliance of the durations of revisions by the teams of DMB (Maintenance Directorate Biskra) and DML (Maintenance Directorate Laghouat).

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Appel à contribution dans la revue Scientifique et Technique de l'Institut Algérien du Pétrole

Le comité de rédaction de la revue Scientifique et Technique de l'Institut Algérien du Pétrole, porte à la connaissance des chercheurs, experts et spécialistes, de la relance de sa revue semestrielle.

La revue se veut ainsi, un espace de réflexion, d'échange, d'écoute et de partage d'expériences sur les problématiques nationales et internationales qui rythment l'évolution des questions énergétiques et offrir ainsi un espace d'expression et d'échange aux spécialistes, aux experts et aux chercheurs nationaux et internationaux, qui sont invités à soumettre des articles.

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