



Study of the lifespan of buried structures using the Weibull approach - case of the GZ1 gas pipeline "HassiR'Mel - Arzew"

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ABSTRACT

The steels of pipelines for the transport of hydrocarbons are stressed by damage phenomena, particularly by corrosion by soils. After detection of these failures by non-destructive testing such as ultrasound or by magnetic flux, the remaining time must be evaluated by a probabilistic approach. This work consists in evaluating the remaining service life of corroded pipes by Weibull approach over a distance of 70km from the Gaz pipeline Hassi R'Mle - Arzew. Inspection results showed peak corrosion depths with a rate of 10-30% of the thickness and two areas damaged by corrosion with a rate exceeding more than 70%. The different reliability parameters namely reliability function, failure function, failure rate, rated life from MATLAB computer code were also determined and discussed.

1. Introduction

Gas production sites are often very far from consumption centers. The gas is then transported by pipelines (gas pipeline) over distances of several thousand kilometers. Transport in economic conditions requires the use of pressures as high as possible, which necessitates the use of increasingly strong steels with adequate properties.

The Gas Pipeline is a structure whose integrity must be guaranteed, in particular, to avoid any priming of faults or ruptures, the sizing of the structure is carried out with an adequate safety coefficient, which authorizes a critical size of defects tenacity to avoid ruining the structure by rapid propagation of cracks. In addition, the fragile ductile transition temperature of the steel is selected to prevent fragile rupture of the tube. An important factor that leads to degradation of pipelines in the oil and gas industry is corrosion. Huge costs are directed annually to mitigate corrosion. Corrosion by soils of buried structures has been undertaken by a number of researchers:

FOCT and GRAS (2003) [1] gathered data from experiments carried out on steels under different environmental conditions in several European laboratories, in order to determine general behavioral trends of these materials, as well as average corrosion rates. The first tests presented concern the influence of oxidizing / reducing conditions on the average corrosion rate of the material. The tests were carried out on specimens buried for 5 years at a temperature of 90 ° C. The results show that the corrosion rate is roughly constant under oxidizing conditions and that it oscillates between 22 and 28 μm/year. Under

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reducing conditions, this is lower, decreases during the test; it is about $5\mu\text{m} / \text{year}$. In other series of experiments, the influence of the composition of the water was studied. It appears that in compact bentonite at temperatures between 100 and 250°C , the corrosion rate is between 6 and $11\mu\text{m} / \text{year}$ and the presence of chlorides at concentrations of about $2\text{ mol} / \text{L}$ does not appear have an influence on the corrosion rate. Corrosion tests were carried out on steel and cast iron specimens: these did not show any significant differences in the average speed over 5 years, whether under oxidizing or reducing conditions. Finally, in the context of waste storage, the high temperature of the latter can play a role in the corrosion of the over-container. Indeed, a series of tests show that the higher the temperature, the greater the average corrosion rate. To summarize these experiments, the carbon content does not have a major influence on the average corrosion rates, on the other hand, the more the temperature increases, and the more the medium is oxidizing, the higher they are. For all of these experiments, the speeds oscillate between 5 and $28\mu\text{m} / \text{year}$.

In this same context, PAPILLON et al. (2003) [2] studied the behavior of steel specimens in compacted clay at 25 and 80°C for 6 months. They measured average speeds of between 4 and $5\mu\text{m} / \text{year}$. In addition, they observed on the test tubes the formation of mixed compounds of iron and calcium carbonates, at the metal / medium interface. These compounds can be either siderite, and in this case the layer is dense, or calcite, porous, which allows the diffusion of iron through it, and the formation of corrosion products between the calcite and the clay. This study illustrates the mobility of ions between the material and the medium.

Much work has been done to estimate the corrosivity of soils. Different countries have developed methods directly linked to the nature of their soils. Note the "Dutch method", using the STARKEY and WIGHT (1945) [3] criterion, intended for marshy, peaty, waterlogged soils (polders), conducive to localized corrosion (anoxia, sulphates, water, etc.). The "English method" CHIVOT (1998) [4] considers only the resistivity and the "Redox potential" of the soil. France CHIVOT (1999a) [5], Germany CHIVOT (1999b) [6] and Italy FOCT and GRAS (2003) [1] are based on standards which define, first of all, an absolute corrosivity index by assigning coefficients to the various characteristics of the soil (nature, resistivity, water content, and pH). A relative corrosivity index also takes into account various heterogeneities observed on the route of the future structure.

A book produced in the United States by ROMANOFF (1957) [7] on behalf of the National Bureau of Standards synthesizes nearly 45 years of experience feedback and laboratory studies, in the United States, on the speeds of «Free corrosion» of metals in soils. This book, despite its age, constitutes a reference database and also a methodology for evaluating soil corrosivity.

More recent "multidisciplinary" type approaches have been carried out over the past twenty years. Unlike the previous ones, these studies take into account the phenomena linked to the nature of the coatings and to cathodic protection STARKY and WIGHT (1945) [8] and show the complexity of corrosion processes. Their merit was to show in a precise way that the risk of corrosion must be analyzed by jointly considering the parameters related to the coating (its mode of degradation in service) but also to the ground. The soil will, in fact, exert a double influence: on the risk of degradation of the coating, but also, according to the mode of degradation of the coating, on the nature of the corrosions which can develop there, and this according to the type of coating defect and local conditions (spatial and temporal) "Scope" of cathodic protection. Another specificity of soils is the presence of electrical disturbances BOOTH et al. (1967) [9], among which we can note the so-called "stray" currents, due to cathodic protection currents of third-party structures or railway lines. Then, we can cite the currents induced by high voltage lines AFNOR (1990) [10], and telluric currents DIN (1985) [11], capable of generating local corrosion in the area of coating defects. Hydrocarbon pipeline steels have been designed for a life more than 70 years, deteriorate slowly while others have already exhausted their useful life in a relatively short time (after a year).

The variation in corrosion rate under dynamic conditions was significant. Annealed steel has the maximum resistance to corrosion YUNTAO and al. (2002) [12], by studying the effect of inclusions of Mn and Mns on the corrosion (SSCC sulfide stress corrosion cracking) of the steels of the pipeline and welds by the effect of hydrogen. BELMOKR and al. (1998) [13] on a study of the underground corrosion of pipeline structures in aggressive soil in the presence of primary polymer coatings show the formation of a passive film formed by sulfates and carbonates on bare steel and which is different for seawater and soil. BENMOUSSAT and al. (2006) [14] and (2011) [15] have shown that API steels are sensitive to corrosion by soils at an almost neutral pH. The study was carried out on a selected simulated soil loaded particularly with carbonate and bicarbonate ions. A discrete analogue of the standard continuous Weibull distribution ARMARNATH and al. 2003 [16] has been proposed in the literature to meet the needs of discrete-time fitting and reliability of survival data sets. Its properties have been studied and the methods for estimating its parameters have also been studied by various authors.

The ultimate pressures of the tubes with defects are obtained from a formulation based on the limited analysis of the defects, BELAID (2008) [17] applied the criteria B31G and B31G modifies to calculate the operating pressure limits for each corroded tube therefore l'assessment of the damage caused by localized corrosion and the fate of the pipeline (reject, undergo a coating,

replace....). ShuXin Li and al. (2009) [18] A methodology is presented for predicting the remaining life of buried pipeline structures with a probabilistic model based mechanically by taking the effect of chance into account in pipeline corrosion. Monte Carlo simulation technique is used to calculate the remaining life and its cumulative distribution function (CDF). Sensitivity analysis is performed to identify the most important parameters that affect pipeline failure. The results show that the depth of the corrosion defect and the rate of radial corrosion are the key factors influencing the probability of pipeline failure and remaining life. The remaining pipeline life can be extended by greatly reducing the average value of corrosion defect depth and radial corrosion rate. CDF is more suitable for characterizing the probability of pipeline failure with respect to the probability density function (PDF) and the reliability index.

RAMDANI and al. (2009) [19] carried out a study on the search for the lifespan of a buried gas pipeline for the transport of gas under high pressure having undergone a natural aging by showing pitting of corrosion in localized form. reliability is achieved using the reliability software PHIMECA SOFT. The reliability index β is determined for three limit state functions. These functions are characterized by KIC in the three stages of the transition curve, brittle, ductile and transient. We are interested in studying the failures in the GZ1 line connecting the natural gas field at HassiR'Mel in Arzew over a distance of 507 km. Failure detection is done by ultrasonic non-destructive testing where an intelligent tool will inspect the internal and external walls of the tubes and detect any failures by corrosion peaks. Interpretation of the results of the tool will determine which failures over seven kilometers where the failures have been observed will need to be replaced or repaired depending on the severity, extent of the corrosion of the pipe. This work is a reliability approach to analyze the lifespan of a gas pipe under localized corrosion. By Weibull approach where the uncertainties are taken into account in the calculation parameters. Thus, the reliability of the tube is calculated by determining the probability of failure or the reliability index.

2. Mathematical models of expression of lifespan

2.1 Lifespan and Reliability

Reliability is defined as a characteristic of devices or works to be expressed by a probability of performing a required function under the conditions of use and for a determined period of time.[20].

We have four concepts in the definition:

- Probability
- Function required
- Terms of Service
- Period

The probability of an event E is obtained:

❖ Either by counting and thus to probability:

$$P(E) = \frac{\text{Number of favorable cases}}{\text{Number of possible cases}}$$

This is the true probability of the event (E). The difficulty is in particular to have access to this count.

❖ Either experimentally: $P(E) \approx F(E)(1)$

$F(E)$ is the observed frequency of the event E the greater the number of observations, the closer this frequency approaches the true probability of having E. $0 \leq P(E) \leq 1$

The required function: it is to accomplish a mission.

The conditions of use: i.e. the operating conditions, the environment, mechanical, chemical, physical constraints, etc.

The time period: this is the duration of the missions in operating units. It is possible to define the reliability by several parameters:

- Failure rate $\lambda(t)$: is a reliability estimator. Indeed, it represents a proportion of device, surviving at time t.
- Repair function $F(t_i)$: it is the possibility that the device is broken down at time t_i .
- Probability of proper operation at time t_i symbol R
 $R(t_i)$: reliability.

We define the complementary reliability:

$$F(t_i) + R(t_i) = 1 \quad (2)$$

■ MTBF (Mean Time Between Failure) or mean time between failure corresponds to the mathematical space of the random variable T, date of occurrence of a failure.

■ The distribution function:

$$F(t).dt = \text{Prob}[t < T < t+dt] \quad (3)$$

Or :

T: failure appearance time.

F(t): probability density.

N_0 : the number of tubes operating at $t=0$.

$N(t)$: the number of tubes operating at time t.

$N(t+\Delta t)$: the number of tubes operating at time $t+\Delta t$.

$N(t+\Delta t) - N(t) = -\Delta N$ (Negative sign because $N(t)$ decreases)

If Δt tends to 0, the estimator tends to a limit which is the instantaneous failure rate:

$$\lambda(t) = -\frac{dN}{N(t)dt} \quad (4)$$

We integrate the function between 0 and t:

$$-\int_0^t \lambda(t)dt = \ln N(t) + K \quad (5)$$

$$N(t) = K e^{-\int_0^t \lambda(t)dt} \quad (6)$$

For $t = 0$, $N(t) = N_0$ where $K = N_0$

$$N(t) = N_0 e^{-\int_0^t \lambda(t)dt} \quad (7)$$

$$\frac{N(t)}{N_0} = e^{-\int_0^t \lambda(t)dt} \quad (8)$$

$$R(t) = e^{-\int_0^t \lambda(t)dt} \quad (9)$$

This last relation is fundamental, whatever the reliability law, it allows an experimental plot of the reliability as a function of time, the variations of the failure time is incurred.

If $F(t)$ and the probability density then:

$$\lambda(t) = -\frac{F(t)}{R(t)} \quad (10)$$

$$\text{MTBF} = \int t \cdot F(t) \cdot dt = \int_0^\infty R(t) \cdot dt \quad (11)$$

The service life can be estimated by a probabilistic approach where three statistical laws are used to adjust the failure appearance phenomenon.

2.2 Weibull's law

Or law with three parameters (η, β, γ) making it possible to correctly adjust all kinds of experimental and operational results.

2.2.1 Area of use:

Weibull's probabilistic mode is very flexible because the law has three parameters to correctly "fit" all kinds of

experimental and operational results.

Weibull's law covers the cases where the failure rate λ is variable and therefore makes it possible to adjust to periods of "youth" and to different forms of aging.

Its use involves the results of tests on samples or the entry of results in operation (TBF = interval between two dates of failures).

These results make it possible to estimate the distribution function $F(t)$ corresponding to each instant t .

On the other hand, knowledge of the shape parameter β is a diagnostic tool of the failure mode in the case where the studied equipment is a "black box".

Graphs of $f(t)$ and $\lambda(t)$:

These graphs show the polymorphism of the Weibull law under the influence of its shape parameter β (fig. 1) BOUMEDDANE (2011-2012) [21].

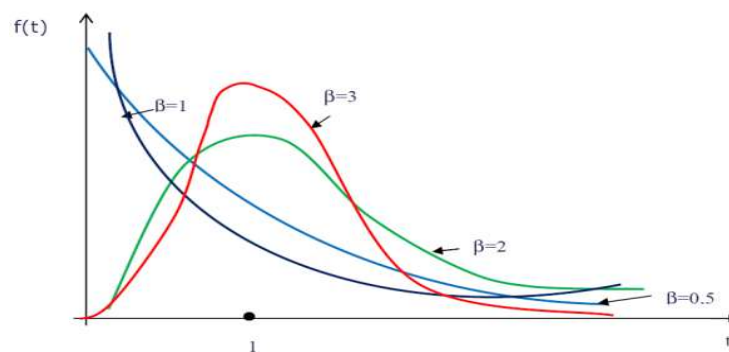


Fig.1-Influence of the shape factor β on the probability density curve [21]

2.2.2 Mathematical Expressions:

Let t be the continuous random variable, distributed according to a Weibull law. [22]

a) Probability density $f(t)$ (Fig. 2).

$$f(t) = \lambda(t) \cdot R(t) \quad (12)$$

$$f(t) = \frac{\beta}{\eta} \left(\frac{t-\gamma}{\eta} \right)^{\beta-1} \cdot e^{-\left(\frac{t-\gamma}{\eta} \right)^{\beta}} \quad (13)$$

With : $t \geq \gamma$

γ : is called position parameters $-\infty < \gamma < +\infty$ (in units of time), it defines a change of origin in the time scale.

β : is called shape parameters $\beta > 0$ (dimensionless), often it is equal to, less than or greater than 1. The "Weibull" law corresponds to an instantaneous, constant, decreasing or increasing failure rate.

η : is called scale parameters $\eta > 0$, sometimes called "life characteristic" it is a simple time parameter.

For example ($\gamma > 0$); there is total survival (no failure between 0 and γ).

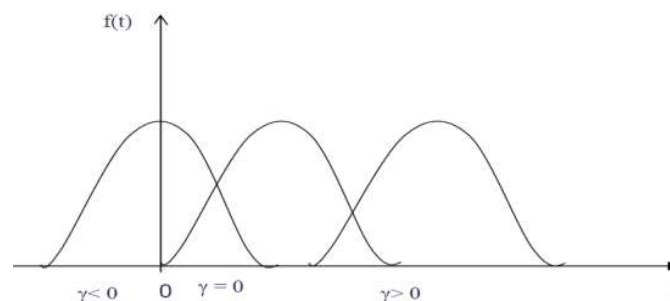


Fig. 2-Curve of density as a function of the position parameter (γ) [22]

Remark :

The parameter β is without dimension the parameter of position and the parameter of scale η (Are in unit of time).

Meaning: γ Indicates the purpose date of failures:

If $\gamma > 0$ There is total survival between $t = 0$ and $t = \gamma$

If $\gamma = 0$ The failures starting at the origin of the times.

If $\gamma < 0$ The failures started before the origin of the times.

b) distribution function:

$$F(t) = 1 - R(t) \quad (14)$$

$$F(t) = 1 - e^{-\left(\frac{t-\gamma}{\eta}\right)^\beta} \quad (15)$$

The corresponding reliability is therefore $R(t) = 1 - F(t)$

$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^\beta} \quad (16)$$

Note: For $\gamma = 0$ and $\beta = 1$ we find the exponential distribution particular case of the Weibull law.

In this case $\lambda = \frac{1}{\eta} = \frac{1}{MTBF}$

c) Instantaneous failure rate $\lambda(t)$

$$\lambda(t) = \frac{f(t)}{1-F(t)} \quad (17)$$

$$\lambda(t) = \frac{\beta}{\eta} \left(\frac{t-\gamma}{\eta}\right)^{\beta-1} \quad (18)$$

with: $t \geq \gamma$, $\beta > 0$, $\eta > 0$

Operation:

- ✓ If $\beta < 1$ then $\lambda(t)$ decreases: period of youth (running-in, burn-in).
- ✓ If $\beta = 1$ then $\lambda(t)$ constant: independent of process and time.
- ✓ If $\beta > 1$ then $\lambda(t)$ increases: obsolescence phase that can be analyzed more finely to guide a diagnosis.
 - $1.5 < \beta < 2.5$: fatigue phenomenon
 - $3 < \beta < 4$: phenomenon of wear, corrosion (starts at time $t = \gamma$)
 - $\beta = 3.5$: $f(t)$ is symmetric, the distribution is "normal"

d) Mathematical time expectation (MTBF)

The average time between two failures corresponds to the mathematical expectation of the random variable T.

The mathematical expectation $E(t) = MTBF$ has the expression

$$E(t) = \gamma + \eta \Gamma\left(1 + \frac{1}{\beta}\right) \quad (19)$$

Γ : function

In which Γ is the symbol of an Eulerian function of the second kind or expression:

$$MTBF = A \cdot \eta + \gamma \quad (20)$$

e) Lifetime t associated with a reliability threshold $R(t)$

We have seen that we can associate at any instant t a probability $R(t)$. Conversely, it is often interesting, from a reliability level $R(t)$, to find the corresponding instant t. In particular, we will note the "nominal" service life associated with the threshold $R(L_{10}) = 0.9$ (generalized notation from the nominal service lives of bearings).

Development :

$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^\beta} \quad (21)$$

Take the natural log of the two members:

$$\ln R(t) = -\left(\frac{t-\gamma}{\eta}\right)^\beta \quad (22)$$

$$\ln \frac{1}{R(t)} = \left(\frac{t-\gamma}{\eta}\right)^\beta \quad (23)$$

$$\left[\ln \frac{1}{R(t)}\right]^{1/\beta} = \frac{t-\gamma}{\eta} \quad (24)$$

where

$$t = \gamma + \eta \left[\ln \frac{1}{R(t)}\right]^{1/\beta} \quad (25)$$

And especially at the threshold $R(t) = 0.9$:

$$L_{10} = \gamma + \eta \left[\ln \frac{1}{0.9}\right]^{1/\beta} \quad (26)$$

$$L_{10} = \gamma + \eta [0.105]^{1/\beta} \quad (27)$$

This lifetime is estimated once the three parameters of Weibull's law have been determined.

Algorithm of the study of Weibull's law:

1. Data entry, inventory of TBFs: The reliability study data will most often come from failure histories, sometimes from test results.

2. We will rank them, order: assigned to each TBF: $1 \leq i \leq N$ The number of TBFs recorded is N sample size.

3. According to sample size N:

*if $N > 50$, we group the TBFs by class, in this case, the cumulative frequency noted:

$$F(i) = \frac{i}{N} \quad (28)$$

Is very close to the distribution function $F(t)$ of the Weibull law.

*if $20 \leq N \leq 50$: we will give a rank i to each failure (we will say: the i th failure).

We use the mean rank approximation formula:

$$F(i) = \frac{i}{N+1} \quad (29)$$

*If $N < 20$ we will use the median rank approximation formula:

$$F(i) = \frac{i-0.3}{N+0.4} \quad (30)$$

3. Industrial Context

a. Description of the GZ1 line

South terminals are all points of the network that are at the root of each south pipeline. Their number has increased as the deposits were discovered. There are currently nine of them, divided between oil field terminals and natural gas field terminals, and this number is set to increase in the years to come. Line GZ1 is installed from Hassi R'mel towards the terminal point in Arzew over a distance of 507 km over which seven (7) natural gas compression stations are allocated as shown in fig.3 and in table 1:

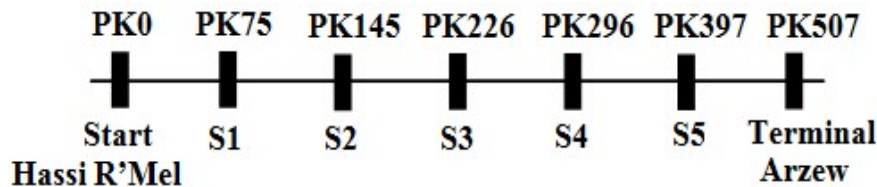


Fig. 3 – line GZ1 showing seven (7) natural gas compressor stations [23]

Each compressor station is made up of three (3) compression turbos with an estimated consumption of 14,000 m³ / h. The terrain through which the pipeline was laid varies between sand, clay, shale and rocks of different natures (non-aggressive, not very aggressive, aggressive) HAFFIF and MEDDAH (2000) [23]

TABLE 1 - Compression Station[23]

Compression Station	Location	Kilometric distance (Km)	Altitude (m)	Ambient T ° C
SC 1 24"	Laghouat	0	747	40
SC 1 40"	Timzert	75	840	40
SC 2 40"	M'sekka	146	4025	40
SC 3 40"	Medareg	226	970	40
SC 4 40"	Nador	295	1255	35
SC 5 40"	Kenanda	397	525	35
Terminal	Arzew	507	20	35

b. Intelligent Tool Inspection

Intelligent tool (Fig. 4) online inspection can provide almost all of the information required for assessing the technical condition of a pipeline. Modern inspection tools, equipped with sensors, must be able to:

- ✚ Travel several hundred kilometers;
- ✚ Detect the anomalies presented on the pipe;
- ✚ Cross elbows with a small radius of curvature; - Overcome vertical pipes;
- ✚ Go beyond incompletely open valves....etc.



Fig. 4 – The intelligent MagneScan HR tool[24]

These scrapers are propelled by the transported product and move inside the pipeline at a speed of between 1 to 4 m / s OULHADJ et al. (2012) [24].

This inspection program revealed a large number of pipeline anomalies, the majority of which were external and internal metal losses;

Recesses;

Construction: anomalies on butt welds ... Manufacturing: laminations, anomalies on longitudinal or helical welds, etc.

c. Data Acquisition

The pipeline of the GZ1 line was the victim of corrosion, the gravity lies in the speed at which it evolved (loss of very advanced metal) because it had exceeded the estimates. In September 1996 the section of gas pipeline GZ1 connecting the compressor station SC2 OuedM'Seka (W. Laghouat) to SC3 Medarreg (W. Tiaret) had been the subject of a metal loss control inspection. This inspection entrusted to PII Group Limited (Canada) Ltd, was carried out by means of an internal inspection tool MagneScan HR allowing an ultrasonic sounding of the wall thickness. Fig. 5 shows part of this line at a distance of 6 km. In Fig. 5, we are limited to choosing a few values, since the section analyzed has several values estimated at more than 10000 lines giving the evolution of the depth of the corrosion peaks. After analysis of the results, we see over the entire length of the pipe considered, the depth of the peaks shown in this figure is between 10 and 30% of the thickness. But there are two areas infected with corrosion that exceed 70%, lying within the fifth kilometer of the starting point of the measurements, the probable causes of this corrosion nest are the presence of aggressive soil or the passage of a river. These results were detected by the smart tool in 1996.

4. Materials and methods

a. Characteristics of the Study Material

Table 2 - Chemical properties[23]

Elements	C (carbon)	Si (silicon)	Mn (manganese)	P (Phosphorus)	S (Sulfur)	Cr (Cromium)	Ni (Nickel)
% in weight	0,2123	0,38	1,35	0,015	0,015	0,025	0,024

Elements	Mo (Molybdenum)	Al (Aluminium)	Co (cobalt)	Cu (Copper)	Nb (Niobium)	Ti (Titanium)	V (Vanadium)
% in weight	0,013	0,067	0,007	0,029	0,078	0,003	0,003

Elements	W(tungsten)	Sn (Tin)	V(Vanadium) +Nb (Niobium)	Fe (Iron)	B (Boron)	S (Sulfur) +P (Phosphorus)	Ceq (Carbon Equivalent)
% in weight	0,004	0,02	0,082	97,8	0,001	0,031	0,45

Table 3 - Tensile test [23]

Trial	Yield strength Re (Mpa)	Tensile strength Rm (Mpa)	Elongation A%	Striction Z%
1	427,1	572,5	31,1	49
2	410,4	556,1	30	53
3	402,3	541	33,5	45
Medium	414,7	553,8	31,33	49

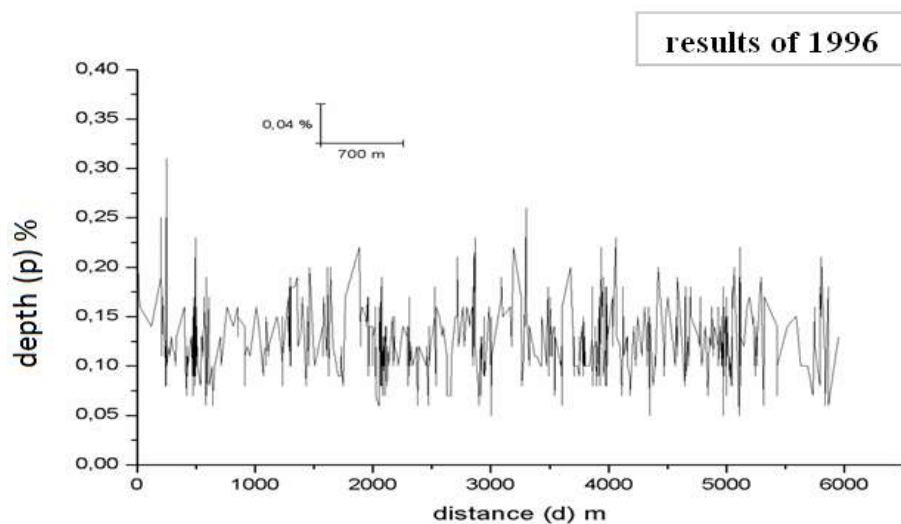


Fig. 5 – Assessment of the depths of the corrosion peaks along a section of the GZ1 [24]

We have developed a program in MATLAB software which, from the operating data of the GZ1 gas pipeline, to define the various reliability functions according to the Weibull model (reliability function, failure function, failure rate, nominal service life and MTBF). We adapt the allowable failure rate can be up to 80% of the tube thickness Based on the probe results, we noticed 19 areas of varying corrosion thickness implying the sample size is 19. We will calculate the corrosion rates of these zones assuming that the rates of each zone are linear and uniform during the operating life of the pipeline in order to calculate each TBF corresponds to an allowable corrosion thickness $E_{cd} \approx 80\% E \approx 10,16 \text{ mm}$ (BELAID (2008) [17]).

Table 4 - classification of good function time results (TBF) by order i

Order i	TBF (i) (Number of years before replacement or repair)	Order i	TBF (i) (Number of years before replacement or repair)	Order i	TBF (i) (Number of years before replacement or repair)
1	21 years	8	72 years	14	86 years
2	42 years	9	72 years	15	89 years
3	48 years	10	72 years	16	91 years
4	51 years	11	75 years	17	94 years
5	57 years	12	78 years	18	97 years
6	64 years	13	80 years	19	103 years
7	67 years	14	86 years		

$$(N = 19 < 20) \rightarrow F(i) = \frac{i-0.3}{N+0.4} \text{ (middle ranks)}$$

The results are shown in figure 5.

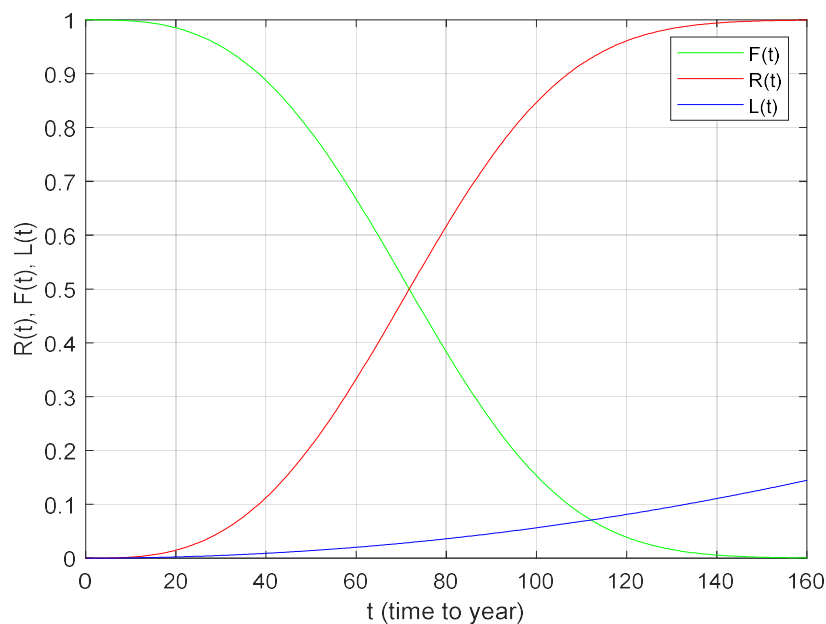


Fig. 5 – Reliability curves, failure rate and probability density.

$F(t)$ is the probability of failure.

$R(t)$ is the probability of correct functioning, it is a decreasing monotonic function.

$R(t)$ and $F(t)$ are complementary probabilities, such that: $R(t)+F(t)=1$

MTBF calculation; $R(MTBF)$; $F(MTBF)$

$$MTBF = A \eta + \gamma$$

$$\gamma = 0$$

$$\eta = 81.106 \text{ years}$$

and $\beta = 3.0048$ by (table 1.3) we have

$$A = 0.8930$$

$$MTBF = (0.8930 * 81,106) + 0 = 71,4276$$

$$R(MTBF) = e^{-\left(\frac{MTBF-\gamma}{\eta}\right)^\beta} = 0.5072 \cong 51\%$$

$$F(MTBF) = 1 - R(MTBF) = 0.49 \cong 49\%$$

5. Results and discussions

The treatment of corrosion data obtained by ultrasonic probe showed that after a period of operation (in our case 20 years of operation), the corrosion depths are different, ranging from 10% to 31% of the walls of the tubes. The reliability functions $R(t)$ the failure rate $\lambda(t)$, the nominal lifetime and MTBF were determined according to the Weibull model by developing a computational code in MATLAB. From these numerical results, we find the value $\beta = 3.75$ ($3 < \beta < 4$), this is the case of the corrosion phenomenon (starts at time $t = \gamma$ in our case $\gamma = 0$).

As shown by the curves in fig.5, the failure rate $\lambda(t)$ presented by $L(t)$ in the figure increases weakly at the start but more strongly at the end, failures are due to age and corrosion. , $\lambda(t)$ increases with time due to the degradation of the pipeline.

The reliability is independent of the age of the structure until the aging period has been reached. During this period of useful life, the structure has a 51% chance of functioning correctly during a period equal to its "MTBF".

We have the phenomenon of failure due to a special cause (in our case the corrosion peaks which are the main cause).

In addition, the calculations showed that the nominal life of the gas pipeline could be up to 73 years.

This study conducted on the gas pipeline; allowed us to determine the reliability parameters ($\gamma, \beta, \eta, \lambda$) and to choose the maintenance policy to apply.

6. Conclusion

The pipes of the GZ1 line of the gas pipeline network are made of API grade 5L X60 steel according to the API (American Petroleum Institute) standard and are protected against external corrosion by hydrocarbon binders (coal tar pitch or petroleum bitumen) and polyethylenes extrudates (PE) supplemented by cathodic protection, the potential of which has been maintained at - 850 mV / Cu / CuSO₄. Two types of failures were noted during the inspections: external corrosion of bare steels in various forms: generalized, localized, pitting, etc. which appeared in areas where the soil is corrosive. These phenomena are worrying for researchers and manufacturers for reliable pipeline transport. The remaining life is estimated using the Weibull model approach; because the study of this lifespan of the gas pipeline, like any other equipment or structure, is determined particularly for failures and the mode of their occurrence.

We found it necessary to compute the three parameters by the MATLAB program; because it allows to reliably adjust all kinds of experimental and active results. Weibull's law also gives the different reliability functions and has advantages in maintenance for estimating the intervention adjustment period, systematic tube replacement and inspection operations using the ultrasound method. There are several models and calculation codes for estimating corrosion failures of pipeline steel surfaces; our project made it possible to understand these phenomena, in this matter, a continuity of this project makes it possible to evaluate and understand more, especially in the field of the evolution of the lifespan.

Nomenclatures

β	Shape Parameters	MTBF	(Mean Time Between Failure), mean time between failure
γ	Position parameters	n	Number of failures
η	Scale settings	ns	Number of survivors
λ	Constant failure rate [nbr/h]	N	Size of a failure sample.
$\lambda(t)$	Instantaneous failure rate	N0	The number of tubes operates at $t=0$.
σ	standard deviation	N(t)	The number of tubes operating at time t.
μ	Repair rate	N(t+ Δt)	The number of tubes operating at time t+ Δt .
API	American Petroleum Institute	P(E)	True probability of the event (E).
CND	Non-destructive testing	PK	Mileage Point
Ep	Tube wall thickness	Req	Average strength of steel (Mpa)
Ecd	Permissible corrosion thickness in (mm)	R(t)	Reliability at time t [%] Probability of proper operation at time ti (the English "reliability" which means "reliability").
Fp	Pitting coefficient	R(ti)	
F(t)	Probability density	T	Fault appearance time
F(ti)	Repair function at the instant ti	TBF	Fault appearance time. (time of good operation before failure)
GZ1	Code of Gas Pipeline N°1 which connects HassiR'Mel and Arzew	Tr	Pipeline expertise time per pig
GPL	Liquefied petroleum gas	Vc	Corrosion rate
i	Rank of the ith failure	W	Wilaya
I	Current injected into the pipeline	xi	The measurements given
L10	The "nominal" lifetime associated with the threshold (R(L10) = 0.9)	yi	The given values
m	Index	Z	Scalar quantity used in the least squares method

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Annexes

Programming results on Matlab

F =

Columns 1 through 13

0.036082	0.087629	0.13918	0.19072	0.24227	0.29381	0.34536	0.39691	0.44845	0.5
0.55155	0.60309	0.65464							

Columns 14 through 19

0.70619	0.75773	0.80928	0.86082	0.91237	0.96392
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r =

Columns 1 through 13

0.96392	0.91237	0.86082	0.80928	0.75773	0.70619	0.65464	0.60309	0.55155	0.5
0.44845	0.39691	0.34536							

Columns 14 through 19

0.29381	0.24227	0.19072	0.13918	0.087629	0.036082
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B = 3.7568

M = 133.01

L10 = 73.005

MTBF = 120.05

RMTBF = 0.50652

FMTBF = 0.49348