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NON-DESTRUCTIVE TESTING BY RADIOGRAPHY OF WELDED SPIRAL TUBES.

CASE STUDY: THE ALGERIAN SOCIETY OF METAL TUBES (ALTUMET)

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***Abstract**: this study aims to deepen a diagnosis by NDT methods in order to know the state of the weld seams of the spirally welded tubes during the manufacturing phase. After a detailed analysis of NDT methodologies, for this purpose, we first place identified the types of weld defect (surface and volume). These defects were the main cause of the constraints in the production of the tubes, at the complexity and diversity of welding parameters (grade, thickness, current, etc.). The obtained results summarize the experimental observations from inspections not destructive by x-rays to the level ALTUMET* **.**

Key words: spiral welded metal tube, NDT, defect, weld bead, inspection, X-rays.

1. INTRODUCTION.

The increase in demand for oil and gas requires the construction of more and more pipeline lines. Indeed, in recent years, they have become the cheapest and safest means of transporting large quantities of energy over long distances (several thousand kilometers). Regardless of where the pipeline crosses (sea or land), it is always exposed to the risk of damage from external or environmental interferences.

In the industry, many parts are often subjected to inspection for safety and cost reasons. The presence of even the smallest welding defect can present a permanent risk that can lead to serious personal injury and property damage. By using inspection and the non -destructive X -ray assessment, the main advantage of which is to restore the controlled part without undergoing any alteration of its physical and mechanical characteristics [1].

The application of non -destructive controls which are very widespread in the industry is the control of welded assemblies where it is known that the obtaining of perfect welding seals is not obvious regardless of the welding process used. Then it remains to locate the defects in the volume of the joint or during use; where he comes to use it with a non -destructive inspection.

The area of welded assemblies is very large; these methods of realization are known by the multiplicity of the parts concerned thanks to their geometric, metallurgical and mechanical characteristics. In this vast area, we distinguished a type of assembly during the manufacture of welded spiral tubes.

The chosen technique of this control (used for the control of the volume of the welded joints) has a particular importance in this field especially for the production of the tubes, and for the safety installations. It is the control by X-ray which constitutes to date themes of research of development and improvement of the methods of inspection of the equipment notably, Rachmasari Pramita Wardhani [2] is interested in choosing to study theorically the radiographic inspection procedure as a non-destructive test in the piping process, N. Nacereddine and all [3] describes their attempt to develop and implement digital image processing algorithms based on global and local approaches for the purpose of automatic defect detection in radiographic images, Christopher T. and all [4]

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give the general overview on the use of radiation devices, effects of ionizing radiations, the Consequences of misusing the devices and the safety precautions taken. The paper recommends to a bide with protective measures when using radiation devices, but S. Deivanai and all [5] in their study examines the volumetric defects in Friction stir welded Aluminium Alloy 2024 pipes.

The objective of the present work aims to identify, locate, study and analyze certain welding defects by radiography of a spiral welded sample tube in Algerian metallic tubes (ALTUMET),

2. ALTUMET PRESENTATION

ALTUMET is an Algerian public company of an economic nature 'EPE' [6].

ANABIB is a real heavyweight in the metal tubes industry in Algeria, knew how for the beginning to win in the market for steel products from second transformation from the start of steel products. Spiral welded tubes with cold profiles, it offers a wide range of products intended for different energy sectors, hydraulics, agriculture, industry and building. Its organization, its mastery of technology and its principles allowed it to build a label and represent a perfect example of the Made in Algeria.

Fig. 1. ALTUMET.

The company's field of activity covers:

- The manufacture of welded spiral tubes from steel strips.
- Coating.
- Record and the development of other manufacturing processes
- Import and export of welded tubes.
- Distribution of products and derivatives such as welded tubes intended for the transport of hydrocarbons, water another various uses (construction supports, piles for drilling).

The manufacture covers a range of steel tubes whose diameter is between 8 and 36 inches (219 mm to 914 mm) delivered bare or coated.
The tubes thus obtained are intended for:
- Transport of fluids:
  - Water,
  - Gas,
  - Oil.
- Metallic construction
  - Construction support (posts),
  - Driven piles for foundations or forging,
  - Lighting support (mats)

The products manufactured by the company are intended to meet the needs for pipes for the transport of water and hydrocarbons [6].
Frequent customers are from the energy sector (Sonatrach) and the hydraulics sector (SEEAL).

2.1. Production line

The spiral welded tube is obtained following a helix, in a forming cage from a cold rolled up strip in accordance with [6]:

- The winding of the strips is adjusted so that the edges of the strips are contiguous at the time of welding; the turns are in alignment with the generatrices of the cylinder that constitutes the finished tube.
- The tubes are manufactured by automatic submerged arc welding under solid flux (SAW); make two passes, one inside and the other outside the tube.
- The edges to be welded sheet must be free of any impurities or internal surface (mill scale, rust, etc.) and will be cut in order to obtain a weld of the highest quality.
- The tube ends are chamfered before undergoing a hydrostatic test.

- The ends of the tubes; repairs and defects detected by ultrasound are x-rayed.
- The tubes thus formed are shipped bare to the park storage, or to the workshop coating for coating.

To ensure the production and control of the tubes, the company has the following material resources:

- 01 Machine de soudage en spirale NLAT.
- 01 machine chanfreineuse.
- 01 hydrostatics bench.
- 01 machine automatic ultrasonic.
- 01 cabin x-ray.
- 01 workshop of the coating to the coating of the tube.

The range of diameters (mm) manufactured at the company level by the machine NLAT are: 406.1 – 457 – 508 – 609 – 711 – 812 – 914.

Machine type	Band width	Manufactured diameter	Used steel (Nuance)
NLAT	680≤L≤120	406 ≤ Ø ≤ 214	E24-x70M

Table 1

Manufacturing Range [6]

2.1.1. Metal tubes description

Pipeline is a conduit intended for the conveyance of gaseous, liquid, solid or multiphase matter, from one place to another. The nominal diameter of a pipe can range from thirty millimeters for special fluids up to more than three meters twenty (sixty-eight inches).

Fig 2. Pipeline **[**photo taken in ALTUMET].

2.1.2. Tube characteristics

Steel pipelines are made by welding short sections of pipe (20 m) together. After the assembly has been x-rayed, the pipe is then wrapped in a protective layer before being buried. All pipelines, without exception, are subject to inspection in addition to being pressure tested before use. These main characteristics (diameters, thickness, type of steel, construction specifications, operating temperature and pressure, etc.) are governed by a whole set of rules and are subject to multiple calculations and economic compromises [7].

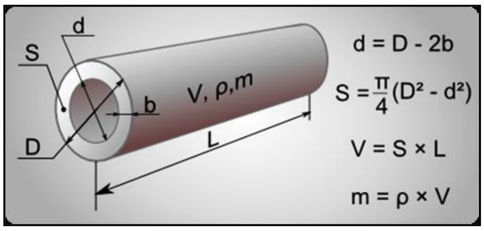

Fig.**3**. metallic tubes characteristics [7].

Pipe diameter is determined according to the flow rate of the products to be transported, their viscosity and their density, so as to achieve an economic compromise between the power of the pumping or compression stations to be installed and the importance of the total investment to be made [7].

2.2. Metal tube manufacturing process

The multiplicity of diameters and thicknesses of the tubes and the development over time of their manufacturing techniques, constitute the reasons for the diversity of the transport network [8], we find:

- Welded tubes in spiral form

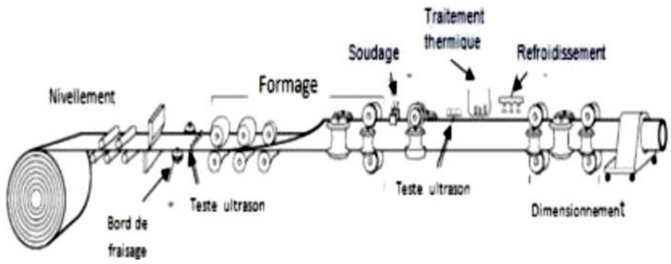

Fig.4. Spiral welding procedure [9].

The company (ALTUMET) receives the raw material which is laminated steel in the form of large coils weighing 13 to 25 tones. They will be checked by measuring its length, thickness, tonnage and detecting surface defects.

Fig.5. Raw material: wound steel

Fig.6. welding machine ATIS.

The manufacturing procedures of spiral welded pipe are made by bending strip of steel sheets in the shape of a pipe and welding them together, this production technique goes through stages, as shown in figure 6. The welding occurs here on the production of the spiral tubes which are usually supplied [10].

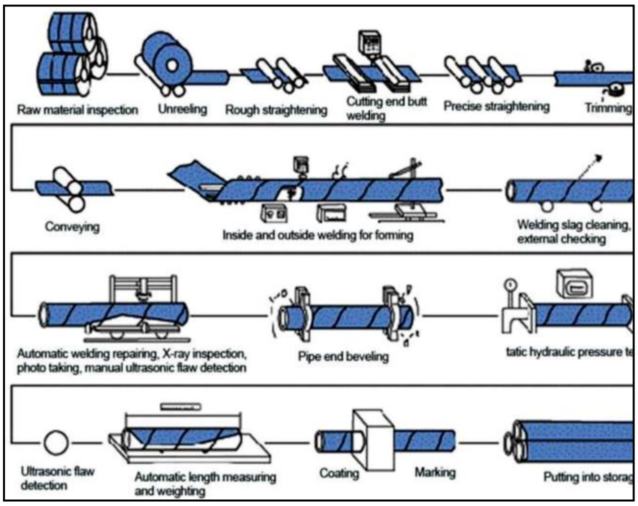

Fig.7. Pipes spiral welded manufacturing technique [10].

Forming of the tube spiral is done with inclination of the angle of introduction of the strip which is calculated by the following relation:

$$\beta = \text{Arscin}\left(\frac{B}{Dext.\mu}\right) \qquad (1)$$

With:

B: width of band

Dext: the diameter of formed tube,

β : the angle of introduction of the band relative to the symmetry axis.

Practically, it is very difficult to fabricate the tubes with a small acute angle, for this, that the values of the angle are limited between 15 and 50.

2.2.1. SAW solid flow arc welding

2.2.1.1. Process principle

Also called: Submerged Arc Welding SAW, consists of making a weld joint on steel using an electric arc that is submerged in powdered flux. This process is performed using a robot, which gives it great regularity. Two robots, positioned opposite each other, can carry out full penetration welding of very thick steel over long distances (several meters). This process is mainly used for the production of mass-produced parts [11].

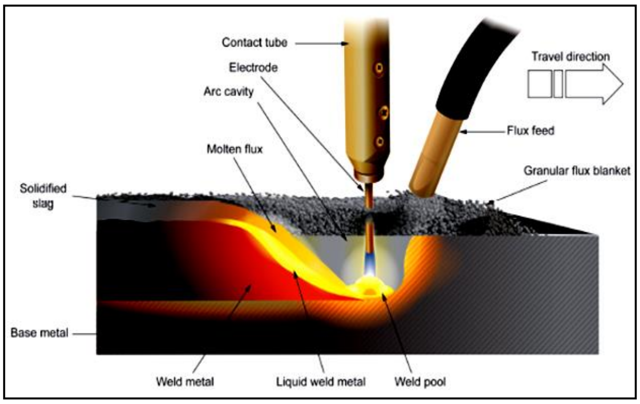

Fig.8. Submerged arc welding process SAW **[**12**].**

This welding process is mainly used in automatic installations. The welding head is connected to the welding generator at its positive terminal; its current is continuous (intensities lower than 1000 amps).

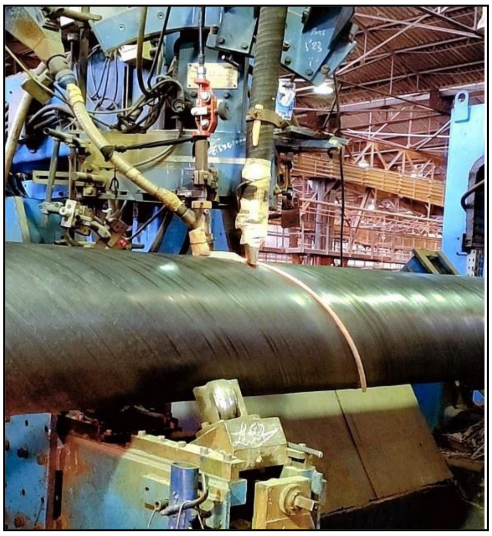

Fig.9. SAW welding (photo taken at ALTUMET).

2.3. Different and main types of welding defects

Classification of welding defects in accordance with standard NF EN 26250.

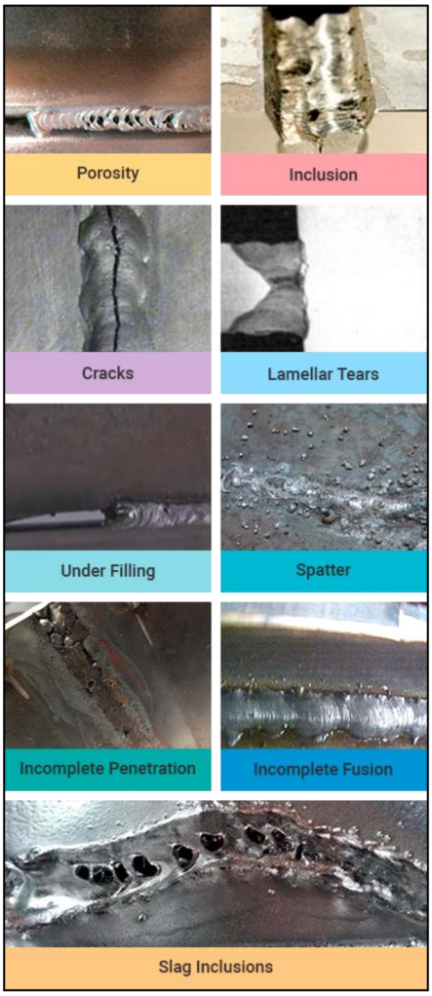

Fig.10. Different types of weld defects [13].

These controls relate to the weld bead. Their goal is to highlight defects that are not visible in particular by x-ray (visual, magnetic particle testing, ultrasonic, x-ray, etc...).

3. Tube inspection

The last test that the tubes undergo is the X-ray test. The detected defects are subjected to a series of high-energy electromagnetic radiation; the results obtained will be interpreted by software that displays the results on screen. Qualified personnel will judge and determine the right tubes to keep defective ones to be rejected.

3.1. X-ray control

Radiography is a non-destructive testing method that uses X or gamma rays in order to visualize the defects that a part or part of it may contain.

To distinguish this type of radiation from other types, such as visible light, X-rays and gamma rays are called penetrating radiation because of their ability to penetrate materials. We are particularly interested in the X-ray inspection process [11].

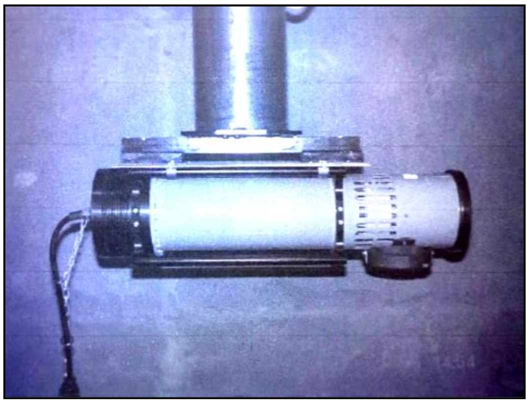

Fig.11. X-ray generator [14].

3.1.1. Principle

This control is based on the differential absorption of X or gamma radiation. The differences in radiation emerging from the room will generate a 'latent image' on the film which will then be revealed chemically.

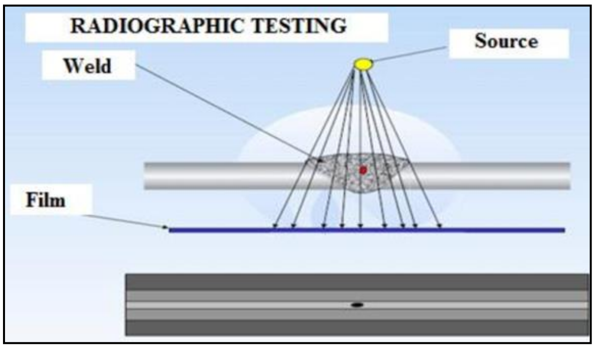

Fig.12. Radiographic Testing [15].

3.2. The experimental procedure

Defects previously detected and located by automatic ultrasonic examination will be subjected to electromagnetic wave radiation from a radioactive X source.
A film obtained will then be viewed on a bright screen to interpret the results and identify defects by qualified personnel.

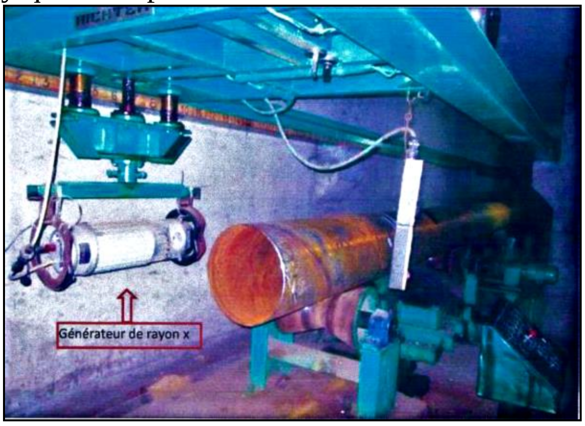

Fig.13. The interior of the X-ray exposure chamber

3.2.1 Preparation of the specimen to be checked

3.3.1.1. Specimen characteristics

Different grades of steels have been used to manufacture the tubes for laying the pipelines. hydrocarbon transport networks are made up of about ten different grades (Grade A, Grade B, X42, X46, X52, X56, X60, etc., X120), bearing in mind that Grade BX52 and X60 represent approximately 70 % of the diversity of these networks [16,17].

The steel used for the manufacture of spirally welded tubes by ALTUMET is X52M, the dimensions of which are shown in table 2.

Table 2

Specimen characteristics

Steel	Diamètres	Thickness	Length
X52M	406 mm	6.35 mm	12.33 m

3.2.1.2. Surface preparation

A metal brush is used to remove irregularities; this will facilitate the interpretation of the radiograms.

3.2.1.3. Identification of the specimen

It is necessary to choose the zero point to put the direction of the reading (an arrow) which put us to detect the defects with precision.
We then take the plug graduated by lead numbers in units of centimeters which will be circled on the test piece to give the fault position.

3.2.1.4 The choice of the IQI

The image quality indicator is DIN 62-10 ISO16 used when the thickness is 5-20mm.

3.2.1.5 Cassette preparation

We take scotch; we put a name on it so as not to contain the film in it.

3.2.2. Parameter adjustment before the check
3.2.2.1 Image quality
3.2.2.1. Calculates IQI sensitivity

The sensitivity of IQI indicates the ability of the entire radiography chain, including the observer, to detect the weakest information (dimension, shape, density). We used IQI of type DIN l.

We used IQI of type DIN l
The fourth is the smallest visible wire, so the sensitivity is:

- S=100 x diameter of the smallest visible thread / thickness to be x-rayed,
- S=100x020/6.35x2
- S=1.58%

Nb: the sensitivity is low which indicates that the image quality is high.

3.2.3. Calculations of the radiographic examination

3.2.3.1. Calculates the visibility index

$$N=a-b \qquad (2)$$

It is a number of smallest threads visible on the film in this case the fourth which corresponds to the number 13.

- b: number of the diameter wire 20% of the thickness to be x-rayed in this case the thickness to be x-rayed e is 12.6 mm (double wall),
- 2%·12.6=0.252 mm which corresponds to the thread of number 11.
- N=13-11 N=2

N: is positive, so the image quality is good.

3.2.3.2. Exposure time calculation

$$T = \frac{Q.D^2.K.N}{A} \qquad (3)$$

With:

- ✓ **T:** exposure time (it must be between 2 and 5 minutes).
- ✓ **Q**: exposure factor (see chart in annex.03) mA· min,
- ✓ **D** : distance source film est génialement de 0.70 m,
- ✓ **K**: coefficient of relative sensitivity of the film (without dim),
- ✓ **mA:** intensity of the current used mA,
- ✓ **N:** coefficient of relative sensitivity of the film) without dim.)

For our experience:

- D=0.70 m d=2 ←→ N=1.4 A=1.4mA K=1
- Q = 4 mA.min for the thickness of 6.35·2mm Then, the exposure time is equal to:

T = 1.96 min = 1min and 56s is the optimized exposure time for radiation protection and image quality.

3.2.3.2 Geometric blur Fg

The geometric blur represents the penumbra zone around an X-ray object; it is due to the non-punctuality of the source.

To calculate the value of the geometric blur we used the following formula:

$$Fg = \frac{d \times b}{Dsf - b} \qquad (4)$$

With:

- ✓ **Fg**: geometric blur mm.
- ✓ **d**: source dimension mm With d =3 mm
- ✓ **b**: the greatest defect/film distance with **b** =13.5 mm
- ✓ **Dsf**: source/film distance, With Dsf =114.3 mm

The maximum value of Fg is given 0.6 mm for Ir-192 then:

$$Fg = \frac{3x13.5}{114.3 - 13.5} = 0.4$$

Fg=0.4 X-ray then monitoring can be done.

3.2.3.3. Pause time (COFREND formula)

$$t = \frac{Kx34xDsf^2xD^{1.42}x2^{\frac{e}{13}}}{A} \qquad (5)$$

t: time of exhibition
K: coefficient of fastness of the film with K=1.9
Dsf: source distance film (meter) with Dsf=0.1143 [m]
D: density referred to D=2.5
e: thickness of the room e=6.35 mm
A: activity of the source A=50 Ci.
e: thickness of the piece e=6.35 mm
A: activity of the source A=50 Ci.
Then:

$$t = \frac{1.9x34x0.1143^2x2.5^{1.42}x2^{\frac{6.35}{13}}}{A} = 0.08min$$

3.2.3.4. Exposure to external contact

The radiographic control of circular welding of a tube with an external diameter of 4' is carried out by a contact pull. The source is placed on the outer wall opposite the weld. Four exposures are carried out for the complete contol of the weld.

The geometric blur represents the penumbra zone around an X-ray object; it is due to the non-punctuality of the source.

3.2.4. Execution of the control

After the presentation of the specimen and the necessary parameters, the expression can be carried out by respecting the following safety rules:

- The beaconing zone: this is the working zone under radiation,
- Chamber walls: the control is carried out in a special chamber consisting of concrete walls 80[cm] thick with a layer of lead 10[cm] to avoid radiation on the radiologists who stay outside of this room.
- The collimator: its role is to direct the radiation beam and limit its propagation in space,
- The remote control: it consists of a control cabin outside the chamber which allows remote control of the device. Stopping exposure should be after the exposure time calculated before.
- Order outside the room which allows remote control of the device. Stopping the exposure must be after the exposure time calculated before.

3.2.4.1. Film processing

Development is done under in actinic light, in the darkroom via automatic development: The film, transported by rollers, passes through the developer, fixer, washing and drying water,

The total processing time is 10-15[cm], the temperature is 25-30°C. After the film interpretation stage using a NEGATOSCOPE, the radiograms must be protected from humidity and excessive temperature (Figure 14 and 15).

Fig.14. Film processor after exposure to X-rays :a) external and b) internal view

- Finally the films are placed in special envelopes.

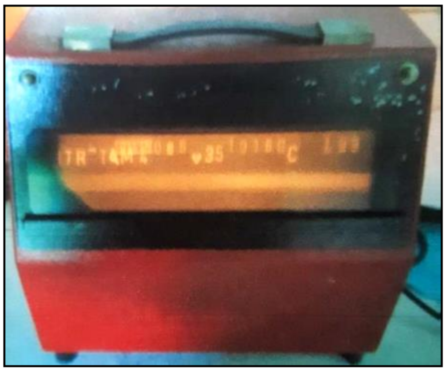

Fig.15. Luminal screen for viewing films (negatoscope)(photo taken at ALTUMET) .

3.3.5. Inspection Results

After the visualization of films by the negatoscope we recorded following results

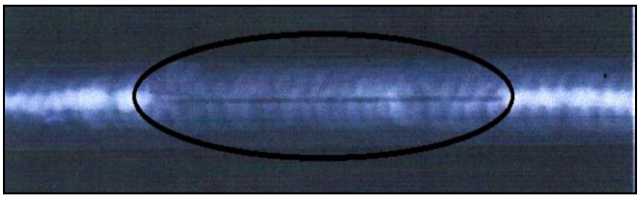

Fig. 16. Defect N°1 (internal channel to the root)

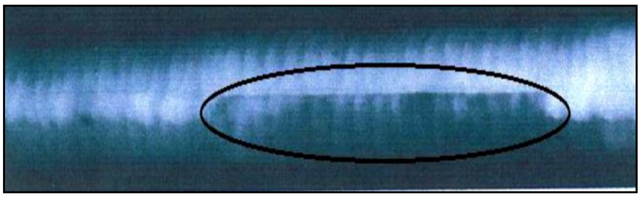

Fig.19. Defect N°4 (lack of penetration)

Fig.17. Defect N°2 (aligned blowholes**).**).

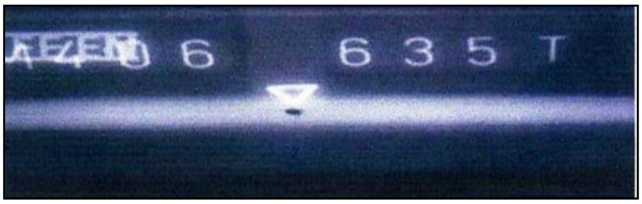

Fig.20. Defect N°5 (isolate blowhole**).**

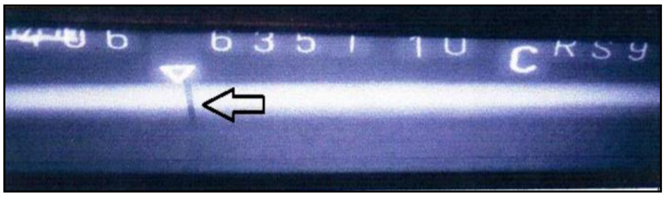

Fig. 18. Defect N°3 (transverse cracks)

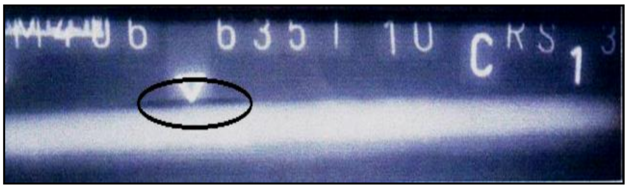

Fig.21. Defect N°6 (external channel**).**

The resultss are resumated in the following table 3

Table 3

Defects identification by X-ray

Defect N°	**Defect position (cm)**	**Lenght (mm)**	**width (mm)**	**Defect type**	**Visualization on the film**
1	[40 à 60]	55	1	Internal channel to the root.	An irregular area of darker density nearby from the center of the solder joint.
2	[60 à 80]	/	/	Aligned blowholes.	Small round dots, the density of which is darker.
3	[80 à 100]	20	3	transverse cracks	A line in the form of feathers, of which the density is darker.
4	[100 à 120]	100	7	lack of penetration	A darker density area.
5	[120 à 140]	Ø = 2mm		Isolate blowhole.	Rounded dark indication, very sharp.
6	[140 à 160]	30	2	external channel	An irregular area of darker density

3.3.6. Results interpretation

X-ray image shows an irregular area of darker density not far from the center of the weld joint and all along the edge of the pass at the root.

1. Defect N°1: Internal channel at the root
On the inner surface along the weld joint, thinning of the base metal causing a ≪ under had to ≫

2. Defect No. 2: aligned blowholes
Radiographic image shows small round dots, the density of winch is darker, in the center of the welded area

3. Defect No. 3: transverse crack
A bill in the deposited metal that crosses the weld. The X-ray image shows a feather-like line, with a darker density that crosses perpendicularly across the width of the welded area.

4. Defect No. 4: insufficient filling at the root of the joint (lack of penetration)
The X-ray image shows an abrupt change in the density of the film in the center of the width of the weld bead, a zone of darker density is noticed longitudinally. (Along the ridge there is a change in density.)

5. Defect No. 5: blowhole isolate
The X-ray image shows a small round dot, the density of which is darker, in the center of the welded area

6. Defect No. 6: External channel
On the outer surface of the weld joint and on the edge of the ridge, thinning of the base metal. The X-ray mage shows an irregular area of darker density. During a channel such as this, the density of this defect will always be darker than the density of the parts to be welded. The faults are shown in the following table

3.3.7. Analysis of the results of x-ray control

The control by x-ray we can detect and locate defects of different nature or the geometry of the difference of density that indicates the type of the defect and its position relative to band encrypted. Defects on films can be broken down into two categories: Linear form defects such as lack of Penetration, which have a length of 100 mm and the gutter with 30 [mm],

Volume shape defects such as blowholes. Linear defects are always unacceptable regardless of their position, because this kind of defects generates a risk on the welded assembly, so we must first meters the lack of penetration which are defect 4 and the gutters which are defect 1 and 6. In a second degree, the volume defects are 3 and 5.

The radiographic control facilitates the repair of defects thanks to the definition of the position, dimension and nature of the defect, another control after the repair is necessary to ensure the elimination of defects (magnetic particle control).

4. CONCLUSION

The main objective of this manuscript is to present a work carried out at the level of the Algerian company of welded tubes ALTUMET Who is the control of the spirally welded tubes in the manufacturing phase and more precisely the non-destructive testing by radiography.

We have found that the manufacture of metal tubes is a very complex process with spiral forming and welding. For a company that manufactures spiral welded assemblies or pipeline pipes, and whatever the manufacturing performance of the tubes, this is not enough for the overall qualification of an assembly.

It must be able to apply several checks to ensure that the quality of its products meets international standards, in particular API requirements applied by ALTUMET, then to guarantee the serviceability of this product and avoid catastrophic incidents. The assembly of the tubes went through several controls including radiographic.

We applied this control on the weld bead line and base metal surface trying to follow and The radiography control allowed us to detect and locate defects of different natures or the geometry of the difference in blackening indicates the type of the defect and its Linear form defects such as lack of position in relation to the in order to make the decision of the conformity and quality of the welds of this tube and the possibility of their repair.

At the level of ALTUMET the welders repair the defects by the SMAW [23], but to avoid these defects there are no very precise remedies, because of the SAW welding parameters and the open place where it is made, so the appearance of certain defects becomes inevitable including blowhole.

To summarize , I would like to specify that this present work is mainly based on the identification of defects in the weld bead of spirally welded tubes, using the non-destructive testing technique by radiography, as a first approach, in one of the most important companies that manufacture welded metal tubes in Algeria, because non-destructive testing techniques remain new in Algeria. Our main contribution was to know how to minimize the presence of defects in the weld seams, in collaboration with the ALTUMET design, manufacturing and development team. This contribution will be the subject of work in perspective.

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ÎNCERCĂRI NEDISTRUCTIVE PRIN RADIOGRAFIE A TUBURILOR SPIRALE SUDATE. STUDIU DE CAZ : SOCIETATEA ALGERIANĂ A TUBURILOR METALICE (ALTUMET) - REGHAIA/ ALGERIA-

Rezumat**:** Acest Studiu își propune să aprofundeze un diagnostic prin metode NDT pentru a cunoaște starea cordonurilor de sudură ale tuburilor sudate spiralat în faza de fabricație. După o analiză detaliată a metodologiilor NDT, în acest scop, am identificat mai întâi tipurile de defect de sudare (suprafață și volum). Aceste defecte au fost cauza principală a constrângerilor în producția tuburilor, la complexitatea și diversitatea parametrilor de sudare (calitatea, grosimea, curentul etc.). Rezultatele obtinute sintetizeaza observatiile experimentale din inspectii nedistructive cu raze X la nivelul ALTUMET.
Cuvinte cheie: tub metalic sudat în spirală, NDT, defect, cordon de sudură, inspecție, raze X**.**

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