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Strategies and Organization Chart Concerning the Technical Diagnosis of Technological Equipments of Type Petrochemical Device

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Abstract

This article presents in a very summary way the necessary phases that must be completed to archive the technical diagnosis of an technological reactor (the checking of the construction documentation and exploitation data, the establish of the degradation mechanisms and the drawing of the verification, examination and investigation program), but also the exemplification of these phases and the conclusions taken about a coking chamber.

Introduction

The normal tendency of any business is the reduction of the production costs. In the processing industries, namely the industry of processing/refinery oil, a major component of the production price, are the expenses with the equipment's maintenance.

The normal decision in this direction, is to use the equipments on their entire life period, but also to find possibilities to extend this period. The progress made over the time in the industry of oil processing and petrochemicals, has made to appear new industrial process, new reaction products that lead to the development of new technological equipments, which vital center it's represented by the petrochemical reactor type devices.

These devices, the petrochemical reactors, through their importance in the technological installation, through the complex process that are taking place inside them, and not least, through the mechanism of degradation to which is subjected the material of construction during the operation, have focused the entire attention of the engineers, in all the phases of their life, starting from the design, construction, exploitation on the standardized period, but also the exploitation over the life period established by the project.

This article tries to establish some basic principles of investigation and diagnosis techniques, that underline the organization of investigation, applied to these types of devices.

The Design

In this phase, the next aspects are very important:

- the maximum voltages depending on load conditions which are limited by a safety factor, so that doesn't exceed either the yield point or resistance to breakage;
- the tasks multiplied with a coefficient that depends on the nature of the material in construction;
- the volume and the type of examinations and tests, that are being put on the equipment (either for the materials mode available to operational requirements, manufacturing standards, either for the welded points or for the entire complex).

In this phase is also made an assessment of the equipment's reliability, considering these issues:

- the loads that action on the structure, including residual tensions;
- the influence of the environment: temperature, corrosive atmosphere, seasonal factors;
- the geometry of structure, especially the welding deformations and geometric irregularities factors that are introducing additional stresses in the structure;
- the properties of materials, which can vary;
- the structure must be designed, so that the original inspection can be possible and also the inspection during service;
- safety coefficients that depend on a careful consideration of the exploitation limit state or ultimate limit state.

The Manufacture

Until the eight decade of the twentieth century, the concept of quality was known by the manufacturers of welded structure, working especially in the nuclear, aerospace, military and petroleum field.

Quality assurance conditions were imposed to the producers by the beneficiaries of the equipments and they were classified according to the next criteria: security, reliability, availability. One of the best know system of this type, it's mentioned as being the one established by ASME Cod for pressure vessels, widely used in USA and Canada, and spread due to the international relations in many countries, on all continents, and especially in the oil sector.

An unitary system, forerunner of the modern quality assurance systems, was designed and implemented in former West Germany with about 40 years ago, as a result of the Germany Institute for Standardization and the German Association of Welding.

In the UK, the quality assurance systems of the producers of welded structures are based on the standards from BS 5750 series, standards underlying the international standards from the ISO 9000 series.

In Romania, the concerns for developing a quality assurance systems for the manufacture of welded structure, has emerged with the development of international cooperation in area such as oil processing, and especially the nuclear energy, manifesting in the same form in all over the world.

It must be mentioned the concern of ISCIR in this area, which as governmental body of technical monitorisation and control in the field of mechanical installation under pressure, has developed and implemented a series of technical prescriptions that have like goals the design, the manufacture, but also the exploitation of these equipments.

Once with the start of the nuclear programme and with the applying of Canadian standards and ASME cod, in Romania appeared the formalist approach of quality, with all her effects (rafting a quality manual, the applying of a quality plan).

For the highest level of quality, the manufacturing plant shall take the following measures:

- to define a quality policy
- to name a person responsible with the application of this policy
- to specify the organization
- the projects and calculations to be performed by a procedure fully defined and verified
- to provide a special control of the supply process
- to develop the manufacturing and inspection plan
- to ensure the traceability for components, subassemblies and assemblies in the working papers
- to prepare, to assemble by welding and to apply heat treatment by following verified procedures
- to scan the operators, but also the inspection equipment and measuring devices
- to define and to implement the procedures of non-destructive examination and for the destructive tests
- to treat the non-conformities and to start the preventive action
- to train the staff in the field of welding and non-destructive examination
- to verify through audits that the measures described above are actually implemented

This formalist approach, required by the equipment destination, was not applied by most of the small and medium companies, because the documents were prepared by AQ specialists and they were difficult to be applied by the executive.

The competitive market, both internal and international, led the manufacturers of equipments under pressure to see in a more realistic way the term “quality” and to develop effective and pragmatic quality assurance systems able to realize even a reduction of production costs.

The Exploitation of the Equipments

During the exploitation of the technological equipments, the inspection work is done both in operation (exterior planned inspections, metal wall thickness measurement, state media, the level of vibrations in the case of the pipes), but also at strict time intervals, according to the technical prescriptions of ISCIR.

Defectology through the 2 methods of its, defectrometria and defectoscopy, can provide the determination of the defect state in the material made operational in a welded structure.

In fig 1 it is revealed the fact that technical diagnosis (the diagnosis of the cessions, in particular and discrete or continuous technical diagnosis in general, are the attributes of any actions of technical monitoring in the exploitation of modern technology

Periodic inspection program for technological devices of type reactor, should be drawn having in consideration the mechanisms of degradations/damage/destruction, the effects that these may have over the metal in construction, operating parameters and also non-destructive and / or destructive examination techniques, that can highlight the appearance and the manifestation of the degradation mechanisms.

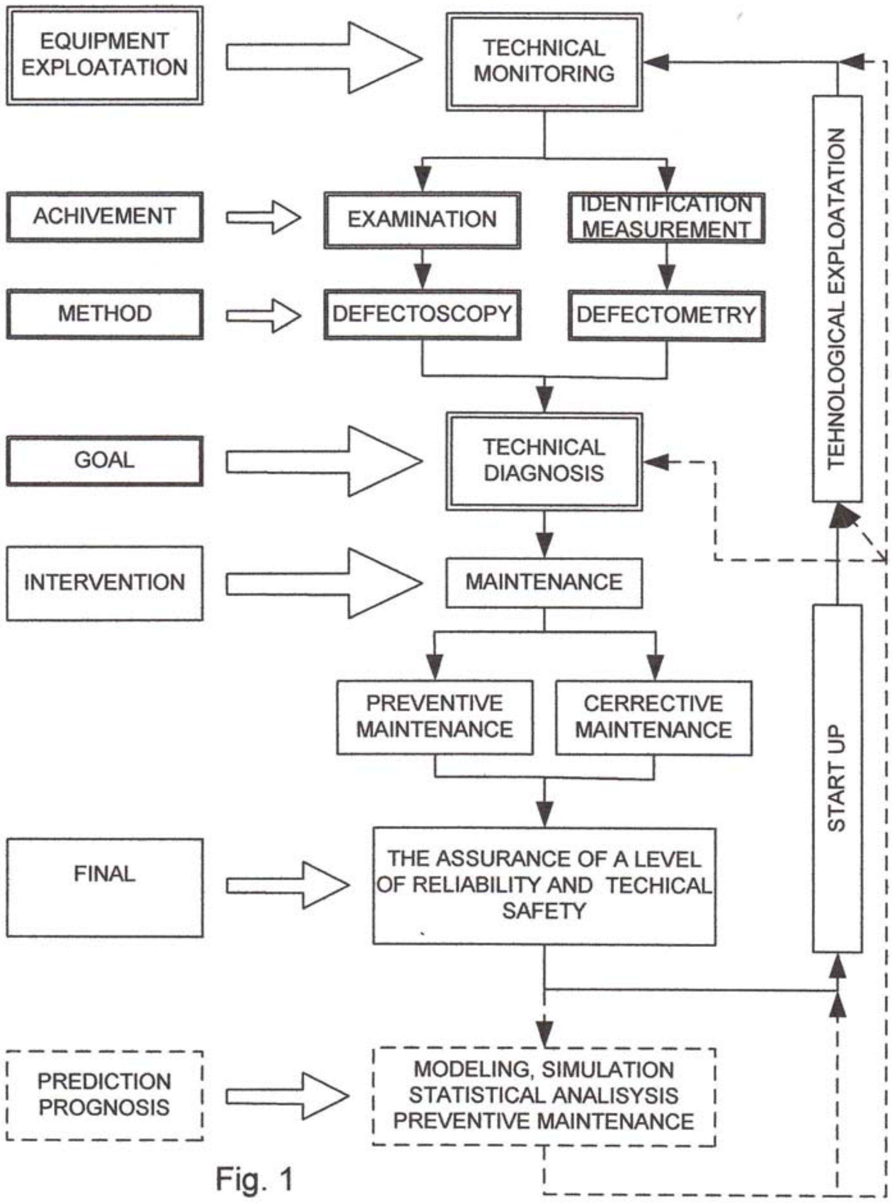

Fig. 1

Case Study

Next we will summarize a case study applied on a cooking chamber after exhausted the standard operational life of 100000 hours from which 50000 hours are to over 420^{0}C (the reference temperature token into consideration in PT ISCIR C4-90) coke chamber R1C.

Phase 1. The analysis of technical documentation

The coking chambers from PLK were designed by ICPUCR in 1973, the execution, installation and registration of this chamber at ISCIR Ploiesti was completed in 1975.

The main design parameters, but also the limit operating parameters of this coking chamber are presented in table 1.

Table 1. Design / operating parameters

Crt. No.	Parameter	Conditions	UM	Limit values
1.	Pressure			
1.1.	Calculation pressure	Top chamber and dome components Upper section Lower section Conical reduction	bar	4.0 5.0 6.0 6.0
1.2.	Work pressure	At the top of the chamber	bar	3.0
2.	Temperature			
2.1.	Calculation temperature	For the metallic wall	^{0}C	495
2.2.	Work temperature	The variation field on the 48 hours	^{0}C	30-495
3.	Working environment	Technological fluid	--	Coke, methane, propane, butane, pentane, hexane, diesel, gasoline
		Fluid category according to Technical order - ISCIR	--	flammable Explosive

In accordance with the operating schedule of the chamber the designer has chosen as a main material for the construction of the coking chamber an alloy steel class C-0,5Mo, respectively, 16Mo5- W1.5423, in accordance with the DIN's symbolism.

There were also highlighted the dates concerning the heat resistance characteristics of the base metal and those for the equipment calculation temperature. These characteristics are presented in table 2.

Table 2. Resistance characteristics

Crt. No.	The characteristic from the technical documentation	UM	Value
1.	Heat resistance characteristics		
1.1.	Technical resistance (creep resistance) at 100000 hours and 495^{0}C [$\sigma^{495}_{R/100000}$]	N/mm^2	107,0
1.2.	Conventional creep technical limit at 100000 hours and 495^{0}C[$\sigma^{495}_{1/100000}$]	N/mm^2	85,0
2.	Size calculation		
2.1.	Calculating allowable voltage for operating temperature of 496 degrees	N/mm^2	69,0

About the dates presented above, there are made the next observations:

a) reference codes in the field – ASME and BS recommends for long lasting use at temperatures above 400^{0}C, the alloy steel of type M-Cr-Mo-V, Cr-Mo, or Cr-Mo-V.

Using steels of the type used in this case steel of type C-Mo it's considered as being part of special cases, where there is best to exist the note of the manufactures. These types of steels have the constant tendency of gradual transition in the grafit of the carbide phases from the microstructure, especially in the field of temperatures above 470^{0}C.

b) according to recent editions of the codes mentioned above, alloy steel of type C-0.5Mo can be accredited with these next calculation tensions, respectively creep characteristics.

The calculation tension at the temperature of 495^{0}C according to ASME II, part D, table 1^{0}, it is of 77 N/mm^2.

It is observed that the value of the allowable tension fa1/100000=69.0 N/mm^2, taken in consideration by the designer in sizing coking chamber is compatible with the recommended values according to some recent documents, based on a substantial volume of experimental data.

c) delivery sheet's status, according to ASME A204, it's in a status of lamination, normalized or normalized and return, and the post welding heat treatment to less than 35mm thickness it's not necessary. This is stipulated only in special cases, like when there is the danger of cracked corrosion under load or the danger of the cracking by hydrogen.

d) during operation, the material of the coking chamber is subjected to high temperatures, but also to some important variations of temperature and tensions. All these things can affect the long lasting behaviour of the equipment, through these next degradation mechanisms. Creep on the field of temperatures above 400^{0}C.

Heat tiredness as a result the of cyclical variations in the pressure and in the temperature.
Steel's decarbonisation at temperatures of more than 200^{0}C as a result of a rich hydrogen environment.

Molybdenum content has a very important role in the strengthening of the crystalline network of steel, in the obtaining of high values of the creep resistance, but it can also provide an increased stability compared with the processes of degradation generated by the combined action of the temperature with hydrogen. At temperatures above 450^{0}Cand especially over 470^{0}C, structural stability can be affected by the processes of graphitization, extremely dangerous.

Also it must be taken in account the fact that as a result of a low level of alloying the steel by 0.5% Mo has a modest reaction towards the general corrosion processes and cracked corrosion under pressure, that occurs when the technological environment contains sulphur compounds.

From these considerents it is indicated as a way of non-destructive examination of welded points, either an examination with magnetic particles, which will highlight the appearance of superficial crazing, or an ultrasound examination, which can highlight the deep defects of the welding columns. Considering the fact that the equipment was manufactured in section and the assembly was done on installing peace it is imposed to be done a visual examination and with magnetic particles, of all the welding cords between the sections, carried out on installing place.

Phase 2. Analysis of the microstructure base material on the coke chamber.

The data that formed the basis of the analysis were provided by the work prepared by SC ICEMENERG SA – Center of electricity and heat production in 2003. In accordance with the specifications in the work mentioned above, metallographic replicas extraction was performed according to SR ISO 3057/1993 and in accordance with the operational procedure of the contractor. It is shown that the replicas examination was made at greatness of x100, x400 and x800. The figures contained in the work contain microstructural issues for greatness of x100 and x400, but not for x800.

The areas of examination by metallographic replicas were in concordance with those for which were made the hardness determination. The test were conducted on the outside and the inside of the shell rings, w III, IV, VII and VIII for each shell ring. The frequency of the determinations was greater in the case of the IV deformed semi shell ring. It has resulted a no of 48 points of analysis.

Table 3. Comparative values of hardness characteristics

Section	Metal ring	Heat	Characteristics of initial state		Actual state
			Rm, N/mm^2	Hardness HV10	Hardness HV10
I	1	117278	591	184	N/A
		117325	520	163	N/A
II	2	117372	535	167	N/A
		117372	538	168	N/A
	3	117392	555	174	167/164
		817352	582	182	172/170
	4	817352	493	154	132/129;123/128;126/127
		117328	530	165	164/171;167/160;166/166
III	5	117392	583	182	N/A
		117392	566	177	N/A
	6	117392	535	167	N/A
		117392	565	176	N/A
	7	117372	538	168	156/154
		117325	524	164	172/170
IV	8	817352	568	178	166/163
		817352	582	182	162/164

Phase 3. Conclusions

a) R1C coking chamber material is subjected to the action of high temperatures, but also the same very important variations of temperature and tension. All these affect the long lasting behaviour of the equipment through the next aspects:
   - Creep in the field of the temperatures above 400^{0}C;
   - Heat tiredness as a result of the cyclical variations of the pressure and of the temperatures;
   - Decarbonisation processes in a rich hydrogen environment;
   - Processes of generalized corrosion and under load broken corrosion.

b) the actual editions of some reference codes in the field. ASME and BS – recommends for long lasting use at temperatures above 400^{0}C, alloy steels of type Mn-Cr-Mo-V, Cr-Mo or Cr-Mo-V. The use of the steels of type C-Mo it’s considered as being part of some special cases, where there is best to exist the note of the manufactures taking in consideration the tendency of gradual transition in the grafit of the carbicle phases from the microstructure, especially in the field of temperatures above470^{0}C.

c) having in consideration the using period of the R1C coke chamber, it appears fully motivated the non-destructive examination – microstructural and of hardness – made on the material of this equipment.

d) analyzing the data contained in the work SC ICEMEMERG, but also in the work SC INOCHEM INTERNATIONAL SA, we can take the following conclusions:
   - the analyses that were made haven’t highlighted important microstructural degradations of the material, determinated by creep processes, excepting the material of the IV semi shell ring;
   - the material of the IV deformed semi shell ring, presents microstructural neomogenities more important and small values of the hardness, comparing to the rest of the coke chambers material.

e) thanks to the specifications from the point d, 2-rd paragraph are imposed/ recommended some supplementary analyses for the IV deformed semi shell ring that can consider the following:
   - verification of the molybdenum content of the steel;
   - verification of the material's decarbonisation by determining the carbon content or microstructures morphology at different depths in the product section.

Conclusions

This article tries to propose an organizational chart (not so required) of the technical diagnosis of an equipment, type chemical reactor. Choice of the case study is because such an equipment, the coke chamber, shows an increased complexity both in terms of degradation mechanisms, including examination and investigation techniques, and in terms of technological process.

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Strategii şi organigrame privind diagnoza tehnică a aparatelor tehnologice de tip reactor petrochimic

Rezumat

Prezentul articol prezinta succint etapele necesare a fi parcurse pentru a realiza diagnoza tehnica a unui aparat tehnologic de tip reactor petrochimic (verificarea documentatiei de constructie, a datelor de exploatare, stabilirea mecanismelor de degradare si intocmirea programului de verificari, examinari si investigati) precum si exemplificarea acestor etape si concluziile aferente pentru o camera de cocs.