PROCEDURAL ASPECTS ON THE APPLICATION MAINTENANCE CONCEPT BASED RISK AND RELIABILITY CENTERED IN THE CASE ASSESSMENT STRUCTURAL INTEGRITY OF EQUIPMENTS FOR INDUSTRIAL PROCESSES

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The essential aspects are presented and discussed specific application of the national concept of risk based maintenance (*RBM*), focused on reliability (*RCM*) and focus on the performance of equipments and facilities in the process industries. Currently, this type of maintenance is one of the most modern and innovative conceptual models which is based on control, monitoring and risk based inspection (*RBI*) and using a specific application procedure with great benefits and superior performance on improving the safety, integrity structural reliability of equipment and industrial installations and reduce costs by eliminating operations diagnostics, control, monitoring and inspections ineffective and increasing the availability of basic technical equipment.

Keywords: risk of failure, matrix of risk, structural integrity.

INTRODUCTION

Although still exists in current practice at many national organizations in the process industries, tend planning and use of preventive control activities, monitoring, inspection and maintenance oriented state-based and prescriptive rules and experience, however, the necessity of and application of existing and conceptual procedures mederne risk based maintenance and reliability centered (*RBM / RC*M) has become almost imminent.

But, actually, the concept of risk based maintenance (*RBM*) is the subject of the present paper has in view the use of a specific application procedures and assessment of the reliability and structural integrity of the equipment and industrial installations and the risks that manifested (RIMAP). This type of maintenance is all the preventive maintenance works based on a large volume of monitoring, knowledge development parameters of major equipment, knowledge and performance characteristics of equipment components, replacement costs of equipment knowledge itself and its components, knowledge and associated costs. This type of maintenance assumes a database on:

- performance of equipments and installations;
- the evolution of in operation parameters;
- monitoring and diagnostic equipments;
- record the events every basic equipments;
- interruptions cost in supply of utilities.

Choosing this type of risk based maintenance and reliability centered feature is dependent on the facilities and equipments that are new, refurbished, ongoing refurbishment or have a normal life to the limit allowed by manufacturers or regulations.

METHODOLOGY OF APPLICATION PROCEDURE

Applying the concept of risk based maintenance and reliability centered (*RBM / RCM*) in the of equipments and installations for industrial processes requests that all related work specific activities (inspection / control, maintenance, repairs, etc.) to be executed by experienced personnel at all levels. Usually, it is recommended that organizational management to consider the composition of complex multidisciplinary teams with expertise in inspection, maintenance, manufacturing materials research, engineering fracture mechanics (mechanisms of damage / degradation, safety and structural integrity), operation and processing equipment and facilities, reliability and risk assessment. In Figure 1, is the procedure for application of risk-based maintenance, which consists of five basic technical steps (RIMAP):

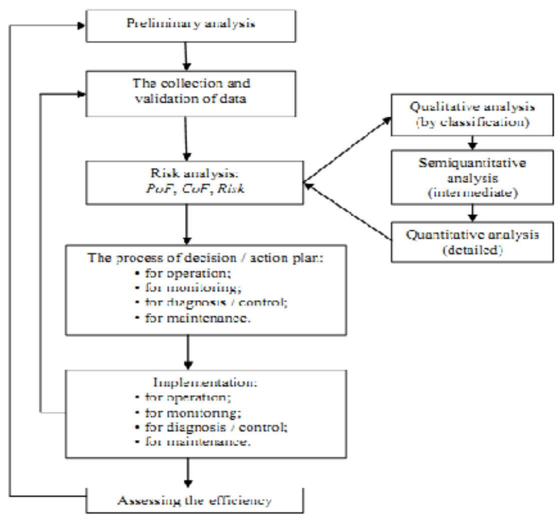

Figure 1. Representation procedure for applying the risk based maintenance (RIMAP)

Additionally the 5 basic technical stages presented above, add a further a technical-organizational stage, defined by evaluating the efficiency. One of the six specific stages procedure for applying the risk based maintenance, with the largest dimension, is the risk analysis on multiple levels.

Preliminary Analysis

This first stage characterized technologically the location (equipments, facilities, components, etc.), establishes objectives and system boundaries considered for analysis (components, main degradation mechanisms, possible failure scenarios and time selected for risk analysis).

For example, in the case of a pipeline technology system within the installations and equipments for industrial processes, defining the limits for technical system analysis shall consider the following:

- components in the system: main pipelines for technological steam (material / steel 12H1MF; pressure P = 150 bar; the working temperature t = 550 ºC; the number of operating hours 141.000; the number of start-stop 142; dimensions of pipe Ø 325 x 38; without incident in operation);
- the main deterioration mechanisms, primarily for simple mechanical stress of creep and mixed, to fatigue-creep;
- the main failure scenario possible: breaking of creep; the secondary, cracking creep-fatigue at due to vibration;

- time selected for risk analysis is for technically system considered 100.000 operating hours, established by the designer (7,5 years) and 200.000 operating hours, the target-objective established for the analysis (15 years).

The acceptability criteria are established by the holder of activity through the regulatory requirements (ISCIR, TRD etc).

The Collection and Validation of Data

The target - purpose of this stage is represented by collection and organization of all relevant data and the information necessary for the analysis. For example, in the case of industrial technological pipeline system analyzed, shall collect the following types of data:

- geometrical characteristics (inside diameter, projection thickness of the wall etc);
- operating parameters (temperature and pressure of design);
- the characteristics of material (average of breaking strength of creep, fatigue strength at a given temperature);
- operating time, in hours;
- parameters monitored (temperature and pressure);
- results of previous test (nil ductility temperature, *NDT*; transition temperature at break with generalized plastic deformation, *FTP*), including the records previous inspection;
- preliminary data calculating (for example, the code ASME, the code TRD/EN 14952).

Risk Analysis

The purpose of a risk analysis is to reduce workloads for the objects with low risk and enhance efforts for the ones at high risk.

The result of this stage is the establishment of a category for the probability of failure (*PoF*) and of another categories for the consequence failure (*CoF*), the corresponding of each component equipment examined. Based on the *PoF* and *CoF*, results of the risk assessment could represented graphically in separate matrix for each type of risk (of technical risks, of OHS, of environmental, of economic and financial etc). Since the creep and fatigue are the principal mechanisms of degradation specific installations and equipment of process industries, determining failure probability (*PoF*), in case of the example considered, is based on exhaustion of creep and on exhaustion of fatigue.

In the present paper is approached first level for qualitative risk analysis (by classification) that uses available data of design of the component under analysis technique, and as additional data, actual number of hours of operation. Through use German technical rules *TRD* (EN 14952), is calculated the working voltage and exhaustion factors (exhaustion of creep, e_z; exhaustion of fatigue, e_w). Definition of classes corresponding for failure probability (*PoF*) and for failure consequence (*CoF*) is utilized for realization of failure scenarios with the help diagram type “bow-tie”, is presented in Figure 2, through an example of application for industrial technological piping system analysis. Thus, for the definition of class *PoF* following are used notation: *PoF Ez* – failure probability based on exhaustion of creep; *PoF Ew* - failure probability based on exhaustion of fatigue; *PoF E* - failure probability combined for *PoF Ez* and *PoF Ew*.

Similary, it is proceeding to defining classes *CoF*, using the following effects and economic consequences of failure: the additional cost of replacement; the typical cost for repair; production loss due to failure; the total cost of replacement; combined costs of repair / loss of production; costs due to additional degradation of the equipment; costs due to replacement / degradation combined; value of replacement; costs breaking of through global degradation.

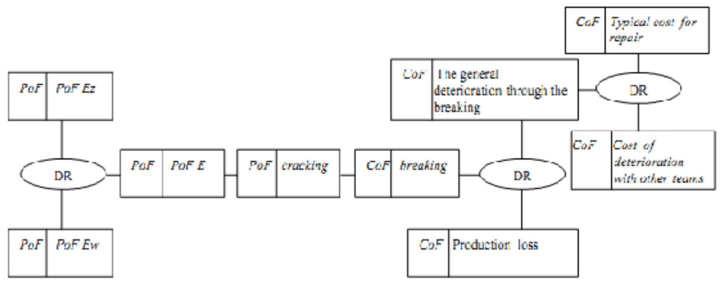

Figure 2. Diagram type “bow-tie” for the technical analysis system

Definition stage aforementioned of the classes is succeeded by the calculation of values their, respectively for *PoF* and *CoF*. In the qualitative analysis of the classification stage 5 classes defined themselves for *PoF* (class 1 - practically impossible, class 2 - highly improbable, class 3 - improbable, class 4 - somewhat probable, class 5 – very probable) and 5 classes for *CoF* (class A - Repair / loss of time, class B - repair or replace the pipe with financial consequences, class C - the breaking and the financial and environmental consequences, class D - breaking and shutdown instalation/ financial and environmental consequences / loss of reputation, class E - additional to the previous class - human casualties / deaths, injuries).

The consequence of failure (*CoF*) was evaluated by examination / diagnostics combined with existing information from service and maintenance history (Heerings *et al.*, 2003; Brear *et al.*, 1994). Having regard *POF* and *COF* values and using the scenario previously defined through the diagram ,,bow-tie" corresponding to each compenent, it is proceeding to determining of risk through it is proceeding to determining of risk through risk matrix corresponding to this first level of qualitative analysis, by using the corresponding classes for these values. In the case of example considered, the risk matrix is presented in Figure 3.

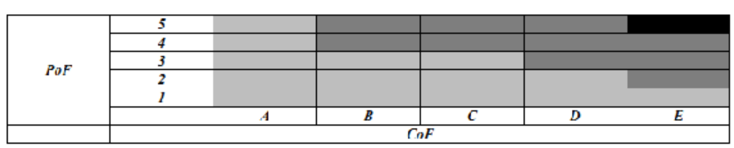

Figure 3. Risk matrix for the qualitative analysis

Since calculated duration for 100.000 operating hours was overcome to this level of risk analysis, is considered that there a probability of the maximum failure and a consequence of the maximum failure, also, probability of failure *PoF* is in class 5, also consequences of failure *CoF* is situated in the class E.

EVALUATION STRUCTURAL INTEGRITY FOR THE TECHNICAL SYSTEM ANALYZED

The evaluation of the deterioration (degradation, destruction) the of the pipe material analyzed in the present paper, in the case mixed request creep-fatigue, in the absence of national regulations is done according code ASME, Case N - 47- 29, Annex T (1990). Thus, according (ASME, 1990; Gusenkov, 1983; Mahutov *et al.*, 1987; Jinescu, 2011), cumulation of deterioration at the mixed request creep-fatigue must satisfy the relation:

$$\sum\left(\frac{n}{N_d}\right)_j + \sum\left(\frac{\Delta t}{T_d}\right)_k \le D \tag{1}$$

in which, $D = 1$ is total deterioration creep-fatigue; $(n)_j$ - number of repetitions applied to the type of cycle „*j*”; $(N_d)_j$ – admissible number of cycles at projection for type of cycle „*j*”, determined from the curve of fatigue (thermal) corresponding to the maximum temperature of the cycle; q – the number of time intervals necessary unique for length of service at the request of creep; $(T_d)_k$ – duration of admissible time determined by extrapolating the curve for technical resistance of duration of creep; should be used maximum strength in pipe by the factor $K^{'}$, according Table T 1411-1 (ASME, 1990). For the deformation ε_t = 0,2% from the curve of fatigue (Jovanovic *et al.*, 2003), resulting value of $(N_d)_j = N_{fmedp}$*=50%* = 37520 cycles.

Considering safety coefficient for the extent of deformation n_e = 2 (Heerings *et al.*, 2003; Brear *et al.*, 1994) and safety coefficient for the number of cycles n_N = 10 [7] for $\Delta\varepsilon_a$ = 0,2/2 = 0,1%, resulting durability N_{fmedp}*=50%* = 26000 cycles. Applying safety coefficient n_N = 10, resulting admissible number of cycles $(N_d)_j$ = 26000 cycles. By doing the report between the number of cycles starting-stopping expected (142), resulting the quota of deterioration of fatigue (thermal):

$$\sum\left(\frac{n}{N_d}\right)_j = 0{,}00546. \tag{2}$$

The values for technical resistance of duration determined by extrapolating through method Larson-Miller for 20.000 operating hours, according Table 1, are represented in Figure 4, below:

Table 1. The values for technical resistance of duration determined by extrapolating

Method	$R_{rmed.}$			$R_{r\,min}$		
	10.000	20.000	30.000	10.000	20.000	30.000
Larson-Miller	99,00	93,9	91,1	79,2	75,12	72,88
Scherby-Dorn	97,3	91,7	88,7	77,84	73,36	70,96

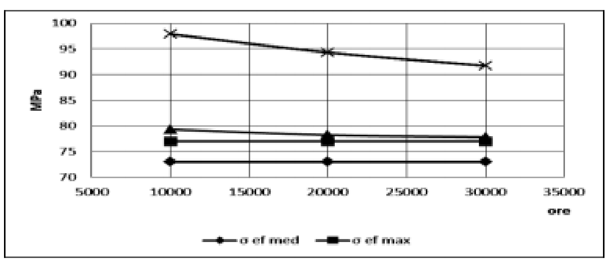

Figure 4. Variation technical resistance time through *Larson-Miller* extrapolation method

The quota of deterioration of creep is determined with the relation:

$$\sum\left(\frac{\Delta t}{T_d}\right)_k = \frac{20.000}{50.000} = 0{,}4. \tag{3}$$

Taking account of the common action creep-fatigue, the sum for quota of deterioration calculated with the relation (1) is 0,40546, inferior the value of 1 (the corresponding for linear summation of deterioration).

In the end, it has been found that besides consumed lifetime for 141.000 operating hours, pipe - thoroughfare can also operate the safe approximately 20.000 hours, according Figure 5.

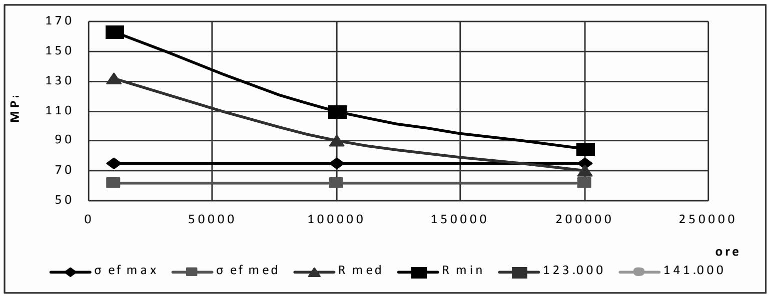

Figure 5. Diagram the life-time

Thus, the probability of failure *PoF* can be framed in class 2 and the consequence of failure *CoF* in class E. That is why, it is recommended non-destructive examination after about 10.000 hours after the consummation 141.000 operating hours, for the detection faults possibly of type fissure, which are very dangerous for such application. Therefore, risk matrix is almost identical to with that of Fig. 3, above.

RESULTS AND CONCLUSIONS

Given that present paper represents a procedural approach for applying the concept of risk based maintenance within the equipment and installations in process industries, is highlighted practical character of it for risk assessment and consequences on the safety and integrity of installations, people, the environment and financial costs.

From the analysis of qualitative risk it follows that technical system studied is characterized by an high risk, which places in the critical area of major risk matrix, also assessment of the state of deterioration of the pipe material analyzed confirm of the one part, the possibility operating safe on the its remaining life and of the other part, the need to apply specific procedures of planning the operations / work monitoring, control and maintenance based on risk generated by the probability of failure in the period remaining life.

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