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A risk-based tool to support the inspection management in chemical plants

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ABSTRACT

The Risk Based Inspection (RBI), proposed by the American Petroleum Institute, is actually the highest benefit maintenance guidelines in the chemical industry, but data collection that characterises this analysis is very complex and time-consuming. The support of the RBI module of the *Inspection Manager* software helps in overcoming such issues as it encloses all functionalities for an easier management of technical data in the Plant's Inspection. The objective of this work is to test the newer version of the RBI module, to achieve this aim some quantitative examples were examined. In addition, by means of the support of such a module, results of the consequence assessment were also compared with those obtained by two commercial softwares in order to verify the *Inspection Manager*'s support in risk-based decisions also when methods for frequency and consequence assessment, different than those of API RBI, are applied and to comment about the available approaches for the consequence analysis.

1. Introduction

The increasing complexity of chemical and petrochemical installations, jointed with the growing sensibility to guarantee higher levels of safety, has determined also an increased attention from designers and operators in finding innovative solutions to ensure safe as well as economically viable operations (Vianello et al., 2013). The loss of containment from process equipments may result in damages to the surrounding facilities and cause serious injuries to the personnel, production losses and undesirable environmental impacts (Modarres et al., 1992; Safe Work Australia, 2012). In this framework, it has become crucial to manage operational risks through the use of effective technology and best practices for inspection and maintenance planning (Abrahamsen et al., 2013; Marhavilas et al., 2011).

Even if several approaches are available in the literature to define optimal inspection frequency (Moura et al., 2015; Sobral and Ferreira, 2015) and to develop maintenance procedures (Bertolini et al., 2009), the Risk Based Inspection (RBI), proposed by American Petroleum Institute (API 580, 2009), is actually the highest benefit maintenance guideline in the chemical industry. The API RBI process aims maintaining the mechanical integrity of equipment items, minimising loss of containment due to deterioration, providing mitigation or prevention measures that can be proposed to avoid damage to the plant and potential injuries to the personnel. The API RBI can be used to identify critical items inside the establishment, where inspections are needed in order to provide the major benefit in reducing the overall risk. The application of this methodology permits a significant reduction of maintenance costs and a simultaneous increase of plant's safety and reliability by constraining costs. The risk calculation consists in relating the failure probability to its consequence; therefore it is important to correctly determine both probability and consequences associated with the leak or the rupture of a component, because an error in their estimation will be propagated to the final risk results and, ultimately, will affect decisions.

A critical issue of the API RBI analysis is the management of several input data, which are needed to perform it; thus for an easier execution of the process the procedure has been recently implemented into a software, named *Inspection Manager*, within a cooperation between the University of Padova and ANTEA S.r.l. (Vianello et al., 2014, 2013). The *Inspection Manager*, in the previous

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release, was only able to manage the results related to RBI analyses, thus within a previous work (Vianello et al., 2013), a new module was added to the software that allows users carrying out a risk-based inspection compliant with API standards. Such a module supports users in applying inspection practices and maintenance planning. This work aims testing this system; moreover, during the validation, the implemented version of the *Inspection Manager* was used to compare the consequence areas of some incidental scenarios, which were estimated by using the standard approach API RBI 581 (API 581, 2008) and two commercial softwares based on the TNO-Yellow Book models (Van den Bosch and Weterings, 2005) and those developed by the EPA (Jones et al., 2013). A case-study allowed achieving the objective of this work and, finally, once the impact zones were identified with respect to thermal radiation/overpressure and toxic concentration, mitigation or/and prevention measures to minimise risk were also suggested.

The paper is structured as follows: Section 2 gives an overview on the API RBI methodology and Section 3 illustrates its implementation within the *Inspection Manager*; Section 4 describes the methodologies used for the consequence assessment supported by the *Inspection Manager*; Section 5 provides some quantitative examples related to the consequence estimation; Section 6 shows and discusses about the results; in the final Section, some comments on the utility of the implemented version of the *Inspection Manager* software are given.

2. API RBI methodologies

The Risk-Based Inspection (API 580, 2009) methodology may be used to manage the overall risk, by focusing inspection efforts on the items with the highest risk level. The base resource document is the API 581 (2008). It provides the basis for decisions about the inspection frequency and its extent and also for the choice of the most suitable type. The analysis may be conducted at several levels (i.e. quantitatively, qualitatively and semi-quantitatively) and the choice of the approach depends on multiple variables, such as the objective of the study, the number and complexity of facilities, the available resources and time, the processes' complexity, the nature and quality of the available data. Fig. 1 shows a simplified block diagram of the API RBI process, which includes the essential elements of an inspection's planning.

The risk calculation by means of the API RBI guidelines involves the determination of a probability of failure (P) combined with the consequence extension of following event (CA), as illustrated in Fig. 2. The risk varies with respect to the time (t) and the previous inspections' effectiveness (Ie) as the failure probability is a function of these variables, whereas related consequence is assumed to be invariant. Thus the uncertainty reduction is a function of the inspection effectiveness in identifying and quantifying the type and extent of the damage.

2.1. Frequencies

The calculation of the frequency of breakage of pipes or other equipment uses a frequency from the literature, then this value is corrected through the following factors: a *damage factor* for the equipment, which takes in account the system's complexity, and a *management system factor*, which quantifies the safety management system efficiency. The API 581 document provides generic values for the frequency of release from several equipments and four breakage dimensions, in order to cover a full range of release scenarios (from small leak to rupture). By assuming a log-normal distribution of the literature data, the frequency of release can spans two orders of magnitude around its mean value and the generic frequency, adopted by the API 581, is the mean value. Then the *damage factor* and the *management system factor* modify the frequency and make it specific for the examined component.

The *damage factor* is essential to account for the damage mechanisms that affect the equipment, which depend on the construction materials and process service, the physical condition of the component, the number and the effectiveness of inspections identifying certain damages. Damage mechanisms can be divided into the following categories:

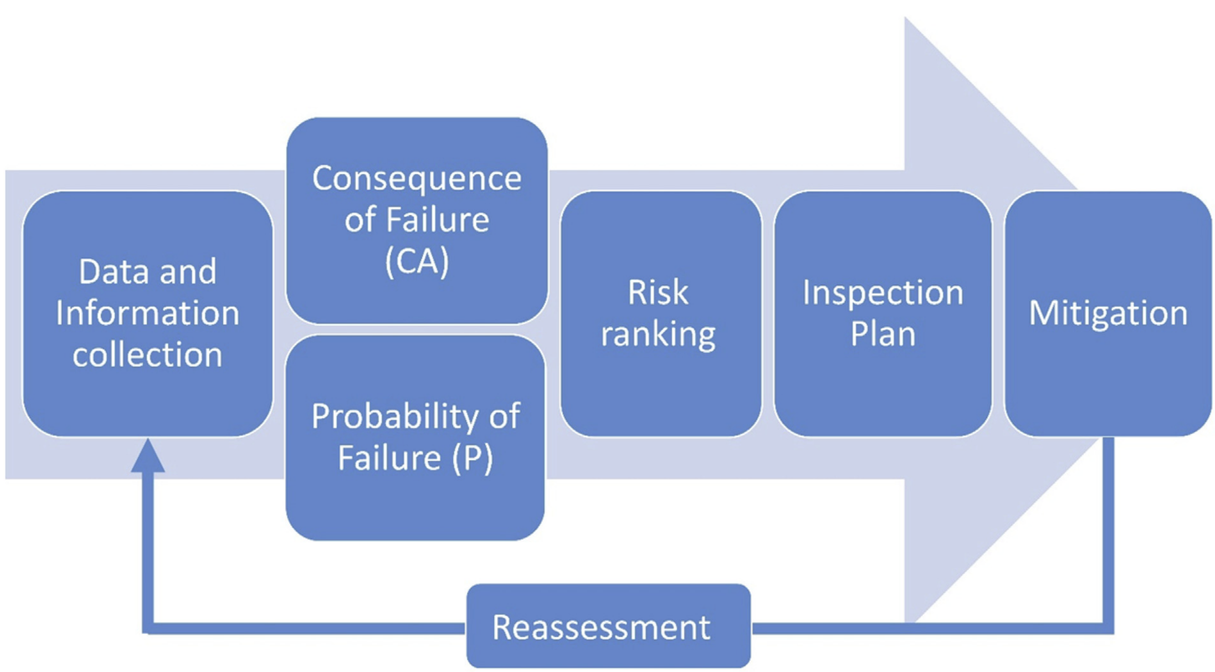

Fig. 1. Block diagram of the API RBI process.