Advances in Reliability, Safety and Security

ESREL 2024
Collection of Extended Abstracts

Material Degradation In Process Industry: Past Accident Analysis

Morena Vitale, David Javier Castro Rodriguez, Micaela Demichela, Antonello Barresi

Department of Applied Science and Technology, Politecnico di Torino, Corso Duca Degli Abruzzi 24, 10129 Torino, Italy.

Keywords: damage mechanism, accident analysis, safety of process, fault identification

In the process industry sector, the progressive ageing of infrastructure can lead to operational problems that can generate containment losses and, in some cases, accidents (Wintle et al., 2006). The ageing of infrastructures does not only depend on the age of the materials, but also on the operating conditions and the substances contained. Factors such as the working environment, the stresses to which the materials are subjected, and the nature of the substances involved play a crucial role in the degradation process (Horrocks et al., 2010). Traditional management systems have proven inadequate in effectively monitoring ageing, primarily due to a deficiency in comprehensive regulations, in understanding of deterioration mechanisms, and in implementation of control methodologies (Hansler et al., 2022).

The Seveso III Directive (2012/18/EU) focuses on the control of the infrastructures ageing and the need for their suitability. However, it does not provide detailed guidance on the evaluation procedures. Bragatto et al. (2017) identify three essential elements to manage and evaluate the ageing of infrastructures:

- data concerning prior incidents and maintenance intervals constitutes essential components for the successful management of infrastructure;
- information acquired through non-destructive testing is a vital element in assessing the conditions of the materials;
- understanding the fundamental physical and chemical mechanisms leading to equipment deterioration can be acquired through scientific research, adherence to engineering principles, and an application of the laws encompassing physics, chemistry, and materials science.

To understand deterioration processes more deeply, different research has focused on the analysis of accidents due to ageing infrastructures. However, they are based on a limited number of events. For this reason, the following study aims to analyse all incidents related to the ageing of infrastructures and the degradation of materials present in the main European and American databases, following the principle of convergence.

A comprehensive historical analysis examined 677 accidents, from 1966 to 2023, in the process industry, focusing on ageing infrastructure. The analysis is conducted with the support of different American and European open-source databases: ARIA, eMars and CSB, using key words such as "ageing", "corrosion", "erosion", "vibration", "wear" and "fatigue". This methodology allowed the creation of a repository, presented in Figure 1, categorizing:

- The industrial macro sectors such as chemical and petrochemical, manufacturing, pipeline, power production, storage and warehouse, transportation, and water treatment (Ricci et al., 2021).
- The final scenarios. They are fire (F), explosion (E), environmental contamination (EC), toxic gas dispersion (TGD), release with no further consequences (R-NFC) or multiple scenarios (MS) defined by Ricci et al. (2021).
- The causes of the accidents, it aligns with the main most frequent deterioration mechanisms identified by Hansler et al. (2022) within the process industry, such as material degradation, corrosion, fatigue,

erosion, and vibrations. The wear-related degradation mechanism was included to ensure a more accurate and comprehensive analysis.

- The equipment was defined by Horrocks et al. (2010). The classification is: primary containment system (PCS), control and mitigation system, electrical control and instrumentation (EC&I) system, and finally structures.
- The substances involved. UNECE (2021) divide the substances as physical hazard, health hazard and environmental hazard.
- The losses involved in the event which can be human, such as injuries and fatalities, or the economic ones, following the classification of Ricci et al. (2023). Furthermore, there are the environmental losses, causing ecological damage or contamination, that can be assessed with a severity scale (Ministero dei Lavori Pubblici, 2001).

The aim of this study is to understand which type of damage to materials occurs most frequently. Analyzing the relationship between this deterioration and the final event that occurs, along with the substances involved in the process, to gain in-depth insight into the ways in which materials degradation within industrial infrastructures. Identifying the areas most susceptible to this type of degradation allows to predict and prevent these events.

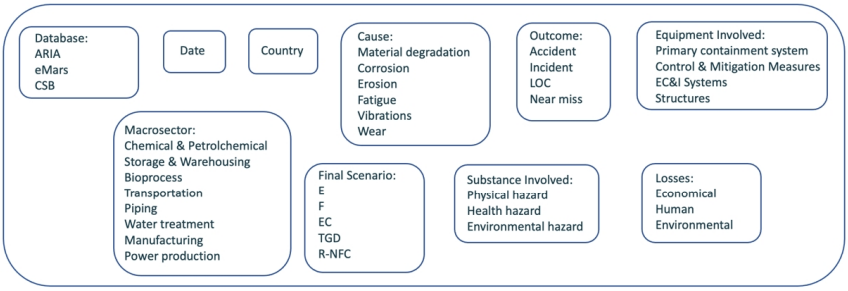

Fig. 1. Repository structure.

The results obtained are fundamental for the development of proactive strategies aimed at minimizing future risks and enhancing preventive measures within the industry, thus contributing to improving the safety and reliability of the entire sector.

Acknowledgements

Part of this study was carried out within the RETURN Expanded Partnership and received funding from the European Union Next-GenerationEU (National Recovery and Resilience Plan – NRRP, Mission 4, Component 2, Investiment 1.3 – D.D. 1243 2/8/2022, PE0000005).

References

Bragatto, P., Delle Site, C., Milazzo, M.F., 2017. Audit of ageing management in plants at major accident hazard. In Proceedings of 2nd International Conference on System Reliability and Safety (ICSRS), 20-22 December 2017, 400–404. IEEE, USA.

Hansler, R.J., Bellamy, L.J., Akkermans, H.A., 2022. Ageing assets at major hazard chemical sites–The Dutch experience. Safety science 153, 105788.

Horrocks, P., Mansfield, D., Parker, K., Thomson, J., Atkinson, T., Worsley, J., Park, B., 2010. Managing ageing plant. HSE, Warrington, UK, Technical Report 823.

Ministero dei Lavori Pubblici, 2001. Requisiti minimi di sicurezza in materia di pianificazione urbanistica e territoriale per le zone interessate da stabilimenti a rischio di incidente rilevante. Decreto Ministeriale 9 Maggio 2001. Supplemento ordinario Nr 151 alla "Gazzetta Ufficiale" n. 138 del 16 giugno 2001 - Serie generale. Italia.

Ricci, F., Casson Moreno, V., Cozzani, V., 2021. A comprehensive analysis of the occurrence of Natech events in the process industry. Process Safety and Environmental Protection 147, 703–713.

Ricci, F., Casson Moreno, V., Cozzani, V., 2023. Natech accidents triggered by cold waves. Process Safety and Environmental Protection 173, 106-119.

UNECE, 2021. Globally harmonized system of classification and labelling of chemicals (GHS), ST/SG/AC.10/30/Rev.9. United Nations Economic Commission for Europe (UNECE).

Wintle, J., Moore, P., Henry, N., Smalley, S., Amphlett, G., 2006. Plant ageing: Management of equipment containing hazardous fluids or pressure. HSE, Warrington, UK, Scientific Report RR509.

Risk and reliability assessment and management