OPERATING EXPERIENCE INSIGHTS SUPPORTING AGEING ASSESSMENTS

M. NITOI

Institute for Nuclear Research, Pitesti, Romania, mirela.nitoi@nuclear.ro

ABSTRACT

Be effective in ageing management means looking at the right aspects, with the right techniques, and one of the most effective tool which could be used for that purpose is the analysis of operating experience.
The paper has as objective to perform a review of available operating experience, with the aim to provide a better picture about the impact of ageing effects.
The IAEA International Reporting System and NRC Licensee Event Reports were chosen as reference databases, both databases being internationally recognized as important sources of information about events occurrences in the nuclear power plants.
The ageing related events identified in the selected time window were analyzed in detail, and the contributions of each major degradation mechanisms that have induced the ageing related events (specific to each defined group of components) was represented and discussed.
The paper demonstrates the possibility to use operating experience insights in highlighting the ageing effects.

Key words: ageing, operating experience analysis

Introduction

Ageing is a complex and progressive process, which begins almost immediately after the component is produced, and it continues throughout their entire life. The ageing process is depending on a various number of influencing co-variables (period of operation, loads, physical properties of materials and operating conditions), and its consequences are related to reduced efficiency of the component.

The ageing process of components, systems and structures can be defined as the continuous time-dependent degradation of materials due to normal service conditions, which include normal operation and transient conditions. [1] The ageing phenomena and it effects represent a significant factor of concern, because of the risk involved by an aged facility operation (it is acknowledged that there is a diminished safety level of the aged facility, as the time is passing).

The effects caused by ageing phenomena may impact on the active, as well on the passive components in the nuclear power plants. In the effort to ensure a reliable and safe operation of the nuclear power plants in long term, these ageing effects should be identified and managed, and maintenance actions should be

implemented, to efficiently control the ageing degradation (to maintain within acceptable limits the ageing effects) and wear out of systems, structures and components.

Another important aspect of systems, structures and components (SSC) ageing is the fact that the ageing related events may result in common cause type failures (CCF), and sometimes these failures may result in failure of an entire component group. As these types of failures are developing slowly, in some cases it is difficult to detect them on time, before the occurrence of the failures. In order to minimize the number of CCF events caused by ageing, certain equipment important to safety may be subject to changes of environmental qualification requirements. These changes may occur to ensure that a safety related equipment can perform its safety function under accident conditions, and the system performance requirements are fulfilled, for the design life of the equipment.

Managing ageing for nuclear power plants means ensuring the availability of required safety functions throughout the all operational plant life, with considerations of changes that occur with time and use. The Ageing Management is defined as the cumulus of engineering, operations and maintenance actions to control, within acceptable limits, ageing degradation and wear out of SSC. Be effective in ageing management means looking at the right aspects, with the right techniques, and one of the most effective tool which could be used for that purpose is the analysis of operating experience.

Ageing management at nuclear power plants should be proactive, so that to timely detect the ageing degradations. After identification of degradations, corrective actions should be proposed to prevent systems and components important to safety from failing, and thus performing their intended safety functions. In an ideal case, when there is implemented a truly efficient ageing management program, the number of ageing related event reports should be quite small. Despite the conjugate efforts to handle the ageing effects, with focus on SSC which are important from safety point of view, the ageing related faults are still occurring.

This paper intends to review the operating experience data, with the aim to provide a better picture about the impact of ageing effects. The final image will be based on the number of events reported that were caused by ageing related faults of systems and components, to perform their intended functions.

Operating experience analysis

Currently, there are 437 operational reactors in the world, particularly 273 Pressurized Light-Water-Moderated and Cooled Reactors (PWR), 84 Boiling Light-Water-Cooled and Moderated Reactor (BWR), 48 Pressurized Heavy-Water-Moderated and Cooled Reactor (PHWR), 15 Light-Water Cooled, Graphite-Moderated Reactors (LWGR), 15 Gas-Cooled, Graphite-Moderated Reactor (GCR) and 2 Fast Breeder Reactors (FBR) [2].
A distribution of outage causes for these reactors [2] is shown in **Figure 1**, and is evident that the first cause for plant outages is represented by equipment failures.

Knowing that ageing degradations have a non-negligible effect on the performances associated with component, systems and structures, it is obvious that ageing effects should be identified and managed correctly, to assure a safe operation of nuclear installations.

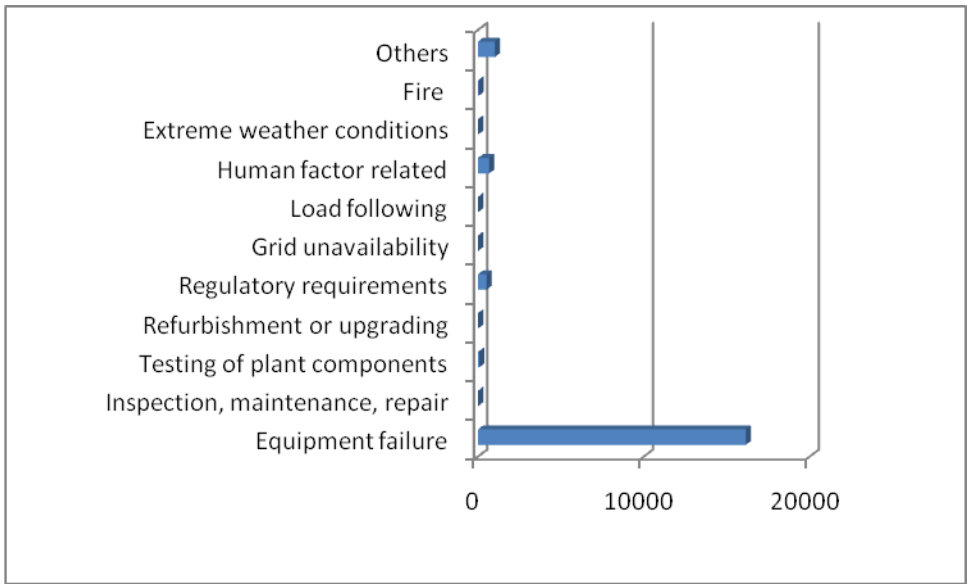

Figure 1 *Distribution of outage causes*

In determining the safety significant components and systems susceptible to ageing degradations, the following methods can be used:

- analysis of operating experience
- expert judgment
- probabilistic techniques, for prioritization of events and for determining risk significance of ageing.

The methods are complementary and for the best results they should be used in combination.

Operating experience analysis is a key factor in improving the operation of all nuclear facilities.
The analysis of operating experience aimed to identify the following:

- proportion of ageing related events from among all reported events,
- components vulnerable to ageing (in terms of most frequently represented in ageing related events),
- most frequent occurred degradation mechanism,
- consequences and impact of events caused by SSC ageing,
- recommendations and lessons learned.

Sometimes, the events are reoccurring because the lessons learnt that may be applicable to similar components or conditions were not adequately or even not taken into consideration. The analysis of root causes, when it is based upon the investigation of an event only, without the knowledge of past experience, may lead to faulty conclusions and may not identify correct the cause of the problem. This fact will contribute to the recurrence of event [6].

The analysis of Event Reports allows the following:

- to identify the extent to which the performance of systems and components has been affected by ageing, and the ageing mechanisms responsible
- to identify methods for detection of ageing degradations
- to identify root failure causes, for selected systems and components

A selection of ageing related events was performed, through revision of the operating experience records. As reference databases to identify relevant ageing related events were chosen IAEA/NEA International Reporting System for Operating Experience (IRS), [4] as well as the US Licensee Event Reports (LER), [5] both data being internationally recognized as important source of information about events occurrences in the nuclear plants. The work intended to identify any event reported to event databases, which was caused by physical ageing of SSC. Only physical ageing of SSC was investigated, the obsolescence related events (becoming out-of-date, in comparison with current knowledge, standards and technology) were not considered.

IAEA/NEA International Reporting System for Operating Experience (IRS) system is hosted by the IAEA, with the objective to augment national operating experience feedback programs.
IRS system provide access to nuclear events information and represents a valuable tool to develop recommendations for improving the performance of nuclear installations, using the lessons learnt from operating experience. There are 32 countries with nuclear programs reporting to IRS, and currently IRS data base contains over 3750 events [4].
Each participating member country designates a national IRS coordinator, and an event report is submitted to IRS when the national coordinator considers that the event is of international interest. Only events of safety significance are reported [3].
The reports can be searched using more options: plant name, reactor type, plant capacity, reactor supplier, start of commercial operation, IRS number, incident date, report submission date, and specific text search [4].

NRC has required nuclear power plants to submit LERs since 1980, and now there are registered 51356 events in the whole NRC database [5]. The licensees should report whenever the conditions are exceeding technical specifications (i.e., those conditions approved for the plant to operate).
NRC LER data base offers the possibility to search these reports using a variety of criteria, including date of occurrence of event, nuclear power plant name, plant operating mode, reactor type, regional location and specific keywords [5].

Due to the fact that each database has its own reporting criteria, and a specific structure, the identification of ageing related events was performed separately for each database.

From analysis point of view, the number of reported events found in the data bases needs to be high enough, in order to allow making credible conclusions, as well as statistical analysis.
As the reporting criteria are different between data bases, and Member States contribution to IRS database is largely based on voluntary contributions, these issues have raised some problems in the unitary analyses of the events.
Related to the number of events recorded in IRS, since only safety significant events are typically reported, the number of ageing related events could have been higher. The ageing related events may not always cause a plant trip or other safety significant consequences, and this fact could impact on the number of reported events [6].

Another issue was raised by the comprehensiveness of event descriptions, a detailed description of failures allowing the identification of ageing related failures much easily. This characteristic allows the identification of representative families of ageing related events, and it will make possible even the trending analysis, that would provide more credible results.
The identification of ageing degradation mechanisms associated to a failure was not easy to make, some event reports mentioned a general ageing degradation, without giving details about a specific ageing

degradation mechanism. Also, sometimes it is difficult to allocate an event to ageing when more factors are contributing to its occurrence.

Identification of the ageing related events from the operating experience databases was made using the following steps:

- Screening the available operational experience databases for a specific period of time, in order to identify the events caused by ageing
- Classification of identified events into selected component groups
- Detailed analysis for identification and evaluation of the root causes, contributing factors, consequences, and safety significance of the selected events

After the preliminary selection, using ageing as a key word, an initial event list has been obtained. In the second step, each event contained in the list was reviewed in detail, to determine its relevance to ageing. This detailed revision is allowing also the identification of the component impacted by ageing, associated ageing degradation mechanisms, consequence on the performance of SSC and the overall ageing impact – at the level of the plant. The results of analysis were summarized for each component groups for which the ageing degradation appeared to be a direct cause.

Results

Initial screening of the events gave the number of reported events caused by ageing, and those events were grouped after into specific components groups.
Categorization of components into specific groups was performed on the basis of major component they belong to; for example, the "relay" group has included any failures associated with ageing of relay coil, and relay contacts.

The following groups were considered:
Mechanical components
This group includes the events related to pipes, tanks, valves, heat exchangers, pumps.
Electrical components
This group includes the following components: circuit breakers, switches, motors, batteries, transformers, electric panels, motor operating valves, Diesel Generators, cables.
I&C components
This group includes the following components: sensors, relays and connectors.

A time window starting from 2000 was chosen for the investigation of ageing related events. Analyzing the behaviour in time of ageing related events (in terms of reported events), no firm conclusions about an existing relation between the number of aged reactors (with more than 20 years of operation) and the number of ageing related events was possible to be made.
A distribution of failures among Electrical, Mechanical, and I&C components is shown on **Figure 2** [4], [5].

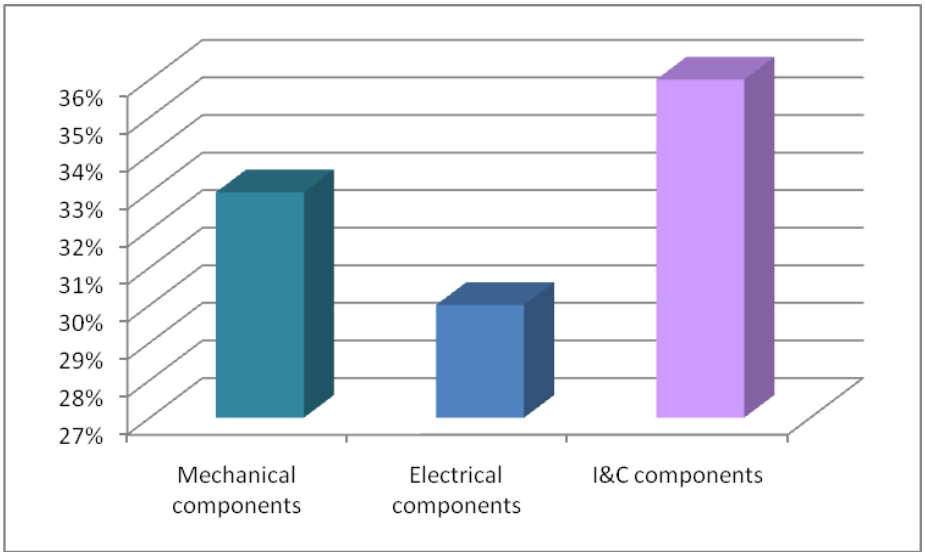

Figure 2 *Mechanical, electrical and I&C components contribution to ageing related events*

According to **Figure 3**, most of the ageing related events were found as corresponding to I&C components, but this may be induced by the consideration of boundaries associated to each group.
As it can be seen from Figure 3, the major degradation mechanisms identified on ageing related events for mechanical components are wear, fatigue and degradation of sealing materials [4], [5], [7].

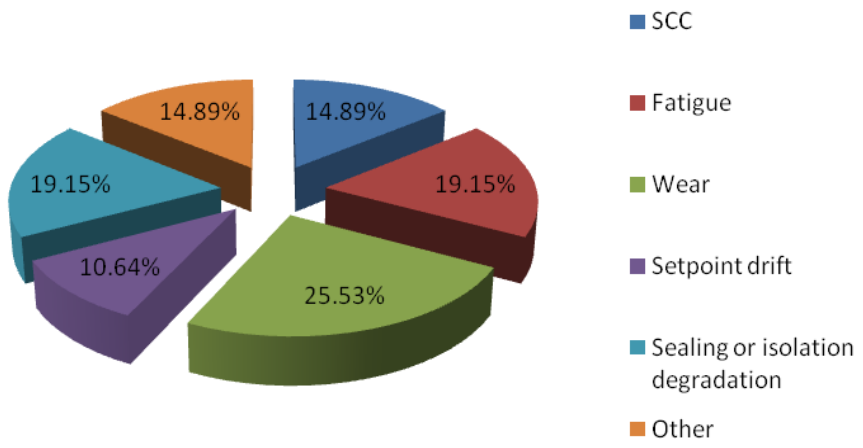

Figure 3 *Degradation mechanisms for mechanical components*

Figure 4 shows the distribution of ageing degradation mechanisms identified in electrical component group. Most common ageing degradation mechanisms associated with these events were found to be insulation degradation and loss of capacity [4], [5], [7].

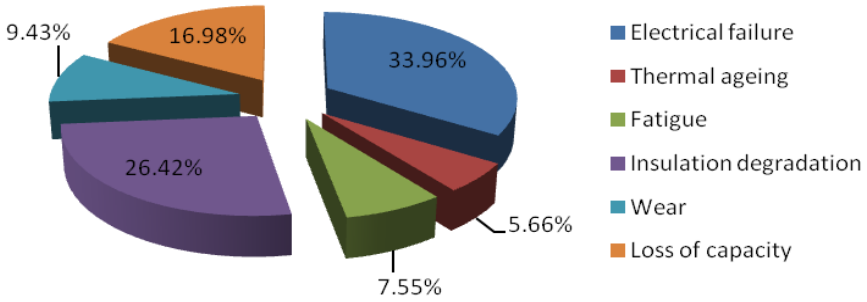

Figure 4 *Degradation mechanisms for electrical ageing related events reported*

There were many cases when the ageing degradation mechanism was not specifically mentioned, and it was recorded as electrical failure. Dominant ageing degradation mechanism identified for this group is "insulation degradations", which was reported for electrical motor and transformer windings, electrical cables and relay coils [4], [5], [7].

For I&C components, the percentage of degradation mechanisms associated to I&C ageing events reported is presented in **Figure 5**. Typical ageing degradation mechanisms associated with I&C components were loss of capacity, insulation degradations, and set point drift [4], [5], [7].

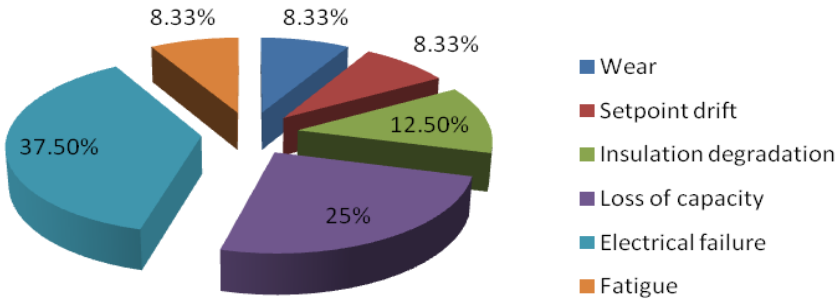

Figure 5 *Degradation mechanisms for I&C components*

The analysis of nuclear power plant operating experience for the chosen period of time has shown that the events involving faults of SSC due to physical ageing were related, in many cases, to performance degradations for equipments, to non-compliance with technical specifications, but they may lead to reactor trips also (**Figure 6**).

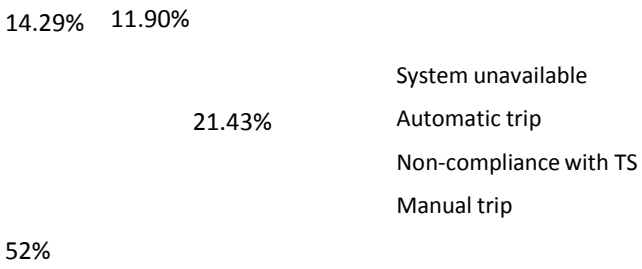

Figure 6 *Distribution of ageing events impacts*

Any failure event related to the following category of SSC:

- SSC important to safety, with the function to ensure the integrity of the reactor coolant pressure boundary,
- SSC important to safety, with the function to ensure the capability to prevent or mitigate the consequences of accidents,
- SSC whose failure may impact safety functions,

is related to critical failures.

In most of the reported cases, the ageing related degradation resulted only in local consequences, and the failure did not propagate further to the plant systems level. However, a significant number of ageing related degradations resulted in a reactor trips [4], [5].

Conclusions

- Ageing related events, the components impacted, and the consequences associated to ageing degradations were identified using the information contained in available operational experience databases. Evaluation of ageing related operating experience could identify several challenging issues and acknowledge important lessons learned; if possible, recommendations on how to tackle ageing related issues for specific SSC should be developed and implemented.
- Besides the information contained in operating experience databases, to evaluate the ageing effects, additional information is necessary (concerning more detailed information on ageing degradation, degradation mechanisms, maintenance data)
- A combination of minor events, involving ageing degradations, may lead to a significant event or an increased risk in operation
- Ageing in combination to inadequate preventive maintenance and deficiencies in operating experience feedback may lead to significant events
- The results of the analysis may be useful in the following:
  - to identify the critical issues related to ageing
  - to develop recommendations for mitigation of ageing effects
  - to evaluate the efficiency associated to existing plant programs (in-service inspection, maintenance, surveillance, equipment qualification) as well as the efficiency of ageing management programs to timely detect the ageing degradation of a specific component, before its failure.

References

[1] TECDOC-540, Safety Aspects of Nuclear Power Plant Ageing, IAEA, Vienna, 1990
[2] PRIS IAEA data base, http://www.iaea.org/PRIS/WorldStatistics/OperationalByAge.aspx
[3] IRS Guidelines, Joint IAEA/NEA International Reporting System for Operating Experience, Services Series No. 19, IAEA, Vienna, March 2010
[4] IAEA/NEA International Reporting System for Operating Experience (IRS), IAEA, Vienna, https://irs.iaea.org/
[5] NRC LER reports, http://www.nrc.gov/reading-rm/doc-collections/
[6] INSAG-23, Improving the International System for Operating Experience Feedback, IAEA, Vienna, 2008
[7] NUREG 1801 – Generic Ageing Lessons Learned (GALL) Report, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1801/index.html