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Baker Engineering and Risk Consultants, Inc., USA, outline a joint fertilizer industry programme designed as a resource to manage damage mechanisms and mitigation options.

A guide for mitigating damage mechanisms

Reliability and safety at fertilizer companies depends heavily on the mechanical integrity of the equipment and piping that are used. In an ideal world, materials could be chosen that are impervious to the deterioration effects caused by ordinary process conditions. In the real world, however, this is either impossible or cost prohibitive, meaning that damage to equipment is generally expected. Companies often have in place an asset mechanical integrity plan that identifies the potential damage mechanisms based on known process and equipment parameters. Management teams develop the facility-appropriate inspection frequencies and methods, and communicate relevant factors and possible mitigation options as a resource for the site.

For the refining industries, the American Petroleum Institute (API) has developed API RP 571, 'Damage Mechanisms Affecting Fixed Equipment in the Refining Industry,'[1] which identifies some common damage mechanisms for typical refinery and chemical process units along with proper inspection techniques and mitigation practices. In addition, API followed RP 571 with the release of API RP 970, 'Corrosion Control Documents.'[2] RP 970 provides guidance on what to consider for controlling corrosion and damage mechanisms on equipment and assets.

The ammonia-related and fertilizer industries have utilised these resources and methodologies along with specific industry knowledge to manage and mitigate the consequences of the known and unknown damage mechanisms in their asset mechanical integrity (MI) programmes, but the available information was often incomplete in some areas. There are unique process conditions in the ammonia and fertilizer industry where certain damage mechanisms are more prevalent and the mitigation options unique. Because of this uniqueness, a joint industry programme (JIP) was initiated in 2020 to conduct a damage mechanism review that specifically addresses ammonia and fertilizer equipment. This JIP will help ammonia and fertilizer companies maintain equipment integrity by providing a foundational basis for managing and mitigating common damage mechanisms, tailored to their experience and needs.

This article discusses the 2020 ammonia and fertilizer JIP for damage mechanisms and mitigation options that draws on ammonia-industry experience and recommended practices to generate a holistic management resource for the plant's asset mechanical integrity and process safety management programmes. This scope was discussed and promoted at the 2019 AIChE, 'Safety in Ammonia Plants & Related Facilities Symposium'.[3]

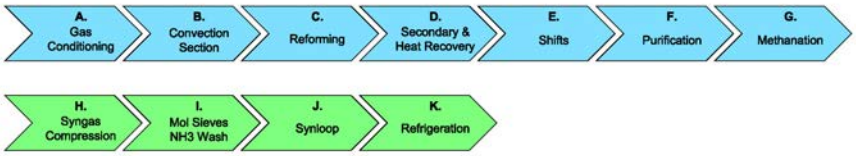

Figure 1. Typical ammonia process production flow block diagram.

Figure 2. Avoiding brittle fracture of a pressure vessel is important in an asset integrity programme.

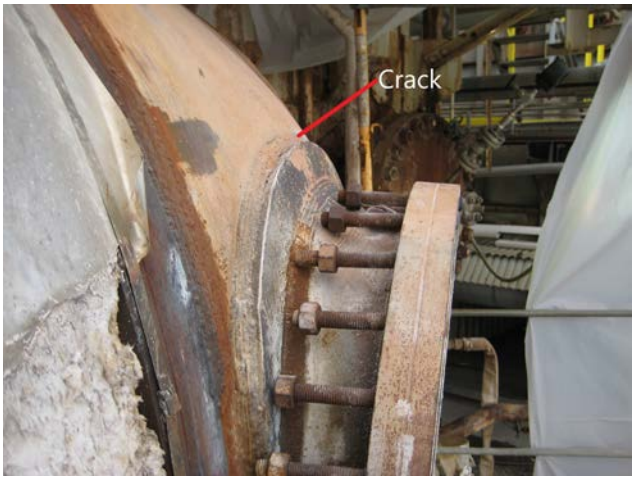

Figure 3. Cracked waste heat boiler manway.

Joint industry programme

The 2020 to 2021 JIP focuses on improving safety and reliability in the ammonia and fertilizer industry. Baker Engineering and Risk Consultants, Inc. (BakerRisk) is facilitating the JIP with multiple ammonia and fertilizer companies that participate in the programme. The first year of this JIP (2020) includes the identification of damage mechanisms and mitigation options for plant equipment in the ammonia process. The overall plan for the JIP provides for subsequent year studies that will address other safety and reliability issues, including damage mechanisms and mitigation options for other fertilizer industry processes such as ammonia storage and loading, urea, nitric acid, and ammonium nitrate.

For the synthesis of ammonia, the front end of the plant prepares a feed stream of fresh syngas: hydrogen and nitrogen in an approximately 3:1 ratio. Normally, the feed stream is free of carbon monoxide (CO) and carbon dioxide (CO_2) and may contain small amounts of water and inerts, such as methane and argon. Figure 1 depicts units that are steps that comprise most ammonia processes. In the JIP, each of these units is reviewed for potential equipment damage mechanisms and mitigation options.

Objective

The objective of the JIP for 2020 is to serve as a resource for identifying and understanding common and unique damage mechanisms applicable and specific to ammonia-related processes. Failures of equipment in ammonia service are of great concern to the industry, with potentially high consequences in terms of injuries, property damage, and business interruption. As part of this JIP, mitigation practices will also be identified and presented that will help reduce the risk of ammonia equipment failures and increase equipment reliability.

Benefits

Many companies do not have the internal resources avaliable to conduct the research necessary to further their understanding of equipment failures and to develop methods to aid in the prediction of such failures. Furthermore, access to damage mechanism experience and information is limited for the ammonia industry.

This JIP utilises pooled funds with technical support from multiple participating companies, and is a cost-effective way both to conduct the research and development needed, and to promote an exchange of valuable information, experience, and successful practices. Information from the AIChE Ammonia Symposium, internal and public incident reports, BakerRisk subject matter experts, and the JIP database searches will provide valuable data that will benefit all JIP participants.

The damage mechanism and mitigation information are designed for use in fitness for service (FFS) and risk-based inspection (RBI) plans to help reduce the risk of equipment failure and plant downtime and increase plant reliability and safety. This information will also provide benefits as an excellent training tool for the technical and operating staff, for conducting HAZOPs that incorporate mechanical integrity input and screening operating procedures to assist in mitigating risk.

Another JIP benefit is the voluntary sharing of safety information, reliability information and lessons learned by the participating companies.

The final JIP document content will include:

- Identifying where damage mechanisms can occur in units.
- Identifying the types of damage mechanisms, including a description of each.
- Discussing affected materials.
- Stating critical factors and parameters.
- Identifying the affected units or equipment.
- Providing mitigation options.
- Adding references/incidents – document known examples when possible.

Damage mechanism concerns

It is easier to find something if you know what you are looking for. While the MI programmes for some process

areas of a plant are easily managed, others are complex and can be affected by changing operating conditions. For the ammonia equipment and piping industries, potentially life-limiting damage mechanisms include high temperature mechanisms such as high temperature hydrogen attack (HTHA), stress corrosion cracking (SCC), general corrosion, fatigue, and brittle fracture, to name a few.[4,5,6,7,8,9] Figure 2 shows the brittle fracture of a pressure vessel, which can be a sudden and catastrophic event.

Awareness of mechanisms that can damage equipment is essential in developing the solution to inspect the equipment properly, mitigate damage, and prevent failure. The pertinent damage mechanisms are also input for evaluations regarding fitness-for-service, and the rate of attack must be understood to determine the remaining life of the equipment. For a proper RBI programme or during the analysis of a hazard, the appropriate mechanisms must be identified so that the probability of failure can be determined when addressing reliability issues.

Identifying the damage mechanisms by the site's MI subject matter expert (SME) is not enough for proper management, as MI interacts with many plant functions such as operations and equipment design. A damage mechanism review (DMR) requires a multi-disciplined team that includes a process engineer and the inspection/reliability SME working with the damage mechanism SME. Operations personnel are also utilised for operating conditions, such as startup and shutdown. Reviewing trended failures, life-limiting damage, and near misses should be included in the DMR.[10]

Damage mitigation options

Mitigation practices are necessary to monitor, evaluate and reduce the risk of ammonia equipment failures and to increase equipment reliability. This can include specific inspection methods that are unique and effective for a specific life-limiting damage mechanism. For example, only certain inspection methods are good for HTHA monitoring.[6] Mitigation could involve protecting the surfaces, such as adding coatings, or inspecting locations for corrosion under insulation (CUI). Some concerns specific to the ammonia industry are mitigating nitriding and internal basket failures on synconverters, as well as the avoidance of cracking in waste heat boilers, as shown in Figure 3.[5]

A tangible benefit for new or replacement equipment is the extension of this past experience, meaning that knowledge in design, materials, and fabrication can lead to more reliable plant operation in the future.

Developing an asset mechanical integrity plan

The process of analysing damage mechanisms and creating an equipment and piping plan begins with identifying a process unit of interest for damage mechanism assessment. The equipment operating conditions, materials of construction and actual type of process are evaluated.

The asset mechanical integrity plan draws on a variety of additional sources, such as a facility siting study for consequence and risk evaluation, to provide a broad perspective that generates a process safety foundation for operations management. Team input is recommended, to provide a foundational document for the site that represents plant functions that can impact the mitigation plan.

The asset mechanical integrity plan includes the following:

- A description of the unit.
- Identified industry incidents and damage mechanisms by unit.
- A list of probable damage mechanisms and failure modes, along with information on each.
- Guidance for operations and process support, such as operating conditions that may impact damage mechanisms, and walk-around field observations such as vibration or insulation damage.
- Equipment limits/applicable integrity operating windows (IOWs).
- Recommended inspection practices.
  - The critical damage mechanism circuits, their potential for failure, and the failure consequence.
  - Critical operational, process, or inspection mitigating factors, and the responsible parties for taking action.
  - Guide to the report's location for additional operational, process, safety, and inspection actions and input.

Summary

The reliability in ammonia and fertilizer company plants depends heavily on the mechanical integrity of the equipment and piping, the development of a good Asset Integrity Plan and knowing the damage mechanisms and mitigation options. The ammonia and fertilizer 2020 JIP for damage mechanisms and mitigation options will be a valuable resource for developing an asset mechanical integrity plan for specific units in the ammonia process. WF

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