Materials safety: article exercise

You are working as a materials expert in your organization and your responsibility is to guarantee safe and efficient use of materials in your facility. One day, a failure in similar facility is brought to your attention, and you need to investigate the possible implications this failure has for your facility. Your job is to interpret and analyze the given failure report and to write a report, which will allow others in your organization to understand the key developments and causes leading to the failure and the necessary actions for prevention of such failures.

Read the given article and analyze the failure. Describe, how the deformation and failure mechanisms presented during the course are reflected in the case and establish the chain of actions leading to the failure. The report should work as an introductory material to your team; it should not be very long but it should enable other team members to understand the key features of the failure without reading the failure report itself.

In addition to establishing the primary cause of the failure, show why alternate failure mechanisms can be ruled out. Some failure mechanisms have not been discussed in the course yet. Conduct the analysis using your present knowledge on the subject.

If the author of the failure analysis has, in your view, neglected to address some aspects of the failure, you may indicate this in your report and suggest tests or actions that should have been done to clarify the issue.

Prepare your response by editing this word document and export it as PDF. The file name identifies you and the article. Do not change the file name (other than the extension to pdf). E-mail the pdf to "materials.safety@iikka.fi".

You may use the question list below to guide you in your analysis:

A. Description of investigation methods applied
- What means of investigation were used in the failure analysis?
- What computational methods were used?
- What material or results were obtained?

B. The primary cause of the failure and description of the failure mechanism
- What is the primary cause of the failure (also provide reasoning)?
- What's the chain of action that led to the failure?

C. Ruling out alternate failure mechanisms
- Can plastic deformation be ruled out? If yes, explain how.
- Can creep be ruled out? If yes, explain how.
- Can brittle fracture be ruled out? If yes, explain how.
- Can fatigue be ruled out? If yes, explain how.
- Can environmentally assisted failure be ruled out? If yes, explain how.

D. Recommendations to prevent similar failures in the future
- How should the design, material, use, etc. be develop to avoid similar failures in the future? Provide several alternatives and indicate most promising.

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Materials Safety analysis report on maraging steel fasteners failure

Problem Overview:

The report investigated the reasons for the failure of maraging steel fasteners used in the nozzle assembly of a satellite launch vehicle. During further torque application, some of these fasteners sheared off at the head-shank junction, indicating a case of delayed cracking. The intergranular fracture, multiple secondary cracks, and anodic dissolution indicates a failure caused by the combined effects of stress and corrosion.

A. Description of investigation methods applied

- **What means of investigation were used in the failure analysis?**

From the report, the means of investigation for the failure analysis included:

1. Metallurgical investigation: The failed fasteners underwent a comprehensive metallurgical examination to discern the cause of failure.
2. Vacuum Induction Melting (VIM): metals are melted in a vacuum chamber to prevent contamination from the atmosphere.
3. Vacuum Arc Remelting (VAR): the material is remelted using an electric arc in a vacuum environment. This is a secondary melting process
4. Hot working

- **What computational methods were used?**

The author lists a couple of computation methods as follows:

1. Optical microscopy: This method observes the threaded region near the fracture edge. It revealed multiple cracks at the thread root, very close to the fracture edge. Additionally, the shank portion was prepared for optical microscopic observations, which showed the fracture path along the fracture edge with multiple secondary cracks.

2. Scanning electron microscopy fractography: SEM fractography was used to analyze the fracture surface. This revealed features such as intergranular fracture modes, corrosion products, pitted facets, and dimple modes of failure.

- **What material or results were obtained?**

Main result: The main results obtained are the identifications of corrosion within engaged threads, intergranular crack propagation and evidence of anodic dissolution. This suggests that the material underwent a type of corrosion where the metal acted as an anode, leading to its dissolution and subsequent cracking.

B. The primary cause of the failure and description of the failure mechanism

- **What is the primary cause of the failure (also provide reasoning)?**

The primary cause of the failure was the corrosion within the engaged threads of the maraging steel fasteners. This corrosion led to the initiation of cracks at the thread roots.

- **What's the chain of action that led to the failure?**

The chronological order of the fasteners' failure is as follows:

1. Fasteners were initially used in a static test, subjected to a sustained load for 2 months. This exposure occurred in a humid saline environment.
2. Later, in another application, the fasteners experienced increased stress. When torque was applied, raising stress to 330 MPa, some sheared at the head-shank junction.
3. Detailed examination showcased corrosion near the fracture edge. Additionally, multiple cracks were observed at the thread root.
4. The fracture's primary mode was intergranular. This pattern is characteristic of stress corrosion cracking in maraging steel.

C. Ruling out alternate failure mechanisms

- Can plastic deformation be ruled out? If yes, explain how.

No, plastic deformation cannot be ruled out. The fasteners were under sustained load in a humid saline environment, which contributed to possible plasticity. When the stress was raised during torque application, the fasteners failed, which can also be a sign of plastic failure.

- Can creep be ruled out? If yes, explain how.

Creep can can be ruled out since there is no sign of heavy static loading for an extended time

- Can brittle fracture be ruled out? If yes, explain how.

Brittle fracture cannot be ruled out because the fracture surface had a predominantly intergranular mode of fracture, which is also an indicative sign of creep fracture.

- Can fatigue be ruled out? If yes, explain how.

Fatigue can be ruled out since there is no cyclic loading during analysis.

- Can environmentally assisted failure be ruled out? If yes, explain how.

Environmentally assisted failure cannot ruled out since this is the main failure mechanism.

D. Recommendations to prevent similar failures in the future

- How should the design, material, use, etc. be developed to avoid similar failures in the future? Provide several alternatives and indicate the most promising.

To avoid similar failures in the future, several design, material, and usage recommendations can be inferred from the paper:

1. Protective coatings: Apply corrosion-resistant coatings or treatments to the fasteners. This can act as a barrier, preventing or reducing the rate of corrosion. Surface treatments on the fasteners can offer added protection against environmental factors.

2. Environmental control: If possible, reduce the exposure of the fasteners to corrosive substances. This might involve changing the storage conditions, using seals or gaskets to prevent moisture ingress, or implementing dehumidification systems in areas where the fasteners operate.