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 collapsed electrical towers in Münsterland

Problem Overview:

The report investigated the reasons for the failure of collapse of several overhead transmission line towers in the Münsterland region of Germany in 2005, primarily due to adverse weather conditions. The event affects 250000 people who lost access to electricity, so the study tries to understand the reasons behind the failure and provides insights based on various tests. Most importantly, a concrete solution must be proposed to prevent further catastrophic events like this.

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. Failure site inspection: a visit to the failure site was conducted, where eleven of the failed electricity towers were inspected. During this inspection, signs of surface corrosion were checked, and it was determined that corrosion-weakening could be excluded.
2. Fracture Surfaces Analysis: The fracture surfaces of the failed components were analyzed. For instance, the fracture surface of the diagonal member M65-04 was examined, and it was observed that the material exhibited signs of brittle fracture.
3. Material analysis: The author studied the properties of Thomas steel used in the construction of the towers. This included understanding the relations between Thomas steel and ageing as a feature of physical metallurgy.
4. Load case analysis: The report compared the calculated tensile forces with experimental fracture forces of components to identify the component that showed primary failure.

- **What computational methods were used?**

The author lists a couple of computation methods as follows:

1. Scanning Electron Microscope (SEM): The fracture surfaces were also cleaned and analyzed under SEM to gain insights into the nature of the fracture, such as intergranular and ductile fracture characteristics.
2. Linear analysis: for the towers, especially considering the codes applicable at the time of their erection (VDE0210:1958), a linear analysis was believed to be sufficient. This analysis helped confirm that the transmission towers met the code requirements at the time of their construction.
3. Comparison with experimental fracture forces: The calculated tensile forces from the derived failure load case were compared with experimental fracture forces of diagonal members from the tower, which helped identify the component that showed primary failure.
4. Force calculations: Forces acting on the components prior to failure were calculated based on the failure load case, which clarified the components under the highest tensile forces

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

Main result: The main results obtained are the failure site images and failed samples, tensile testing of structural parts, materials investigations & fractography, fracture surface analysis, and load case analysis. These results provided a complete explanation for the failure mechanism and the external factors that contributed to the collapse of the transmission towers.

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 of the transmission towers was identified as the brittle fracture of the diagonal member M65-04 made of Thomas steel. The report mentions that brittle fractures are not typical for this type of mild structural steel. However, the embrittlement localized around the stamped holes of steel profiles made of Thomas steel was identified as a significant factor contributing to the brittle fracture. The subsequent failures of neighboring diagonal members were a result of similar brittle fractures due to the sudden increase in their load following the initial rupture.

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

The chronological order of the transmission towers' failure is as follows:

1. Initial embrittlement and brittle fracture: The diagonal member M65-04, made of Thomas steel, experienced embrittlement around the stamped holes
2. Subsequent failures: As a direct consequence of the rupture of the diagonal member M65-04, the neighboring diagonals M65-01 and M65-02 experienced similar brittle fractures.
3. Large deformation and tower collapse: The combined failures of these diagonal members caused significant deformations in the tower beneath the cross arms. Without adequate bracing to support the structure, the main legs of the tower buckled, making it collapse.
4. Consideration of other failure mechanisms: While other potential failure mechanisms, such as stability failure by buckling of single highly stressed diagonal members, were considered, they were ruled out as primary failure causes.

C. Ruling out alternate failure mechanisms

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

Plastic deformation can be ruled out since the failure occurred predominantly due to brittle fracture caused by embrittlement in specific areas of the tower components.

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

Creep can be ruled out since it is more pronounced at elevated temperatures. The failure of the towers in Münsterland occurred during severe weather conditions with snowfall, implying colder temperatures. This is not the typical environment where creep would be a failure mechanism.

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

No, it cannot be ruled out since it is the main reason stated in the report.

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

Probably no. The cyclic loading of the snow during the winter, while the nature of loading is stochastic in itself, can induce some fatigue on the diagonal members.

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

Environmentally assisted failure can be ruled out since during the failure site inspection, the report mentions that signs of surface corrosion were not found on the towers. As a result, corrosion-induced weakening of the structures was excluded as a cause of failure.

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. Material Conditions: Ensure thorough inspection and assessment of the materials used in the construction of transmission towers. This includes understanding their susceptibility to embrittlement, and their performance under various environmental conditions.

2. Load assumptions: Reassess the load assumptions, especially in regions prone to severe weather conditions. The assigned ice loading zone should be reviewed to ensure that the towers can withstand the maximum expected loads.

3. Prevention of Embrittlement: Given that embrittlement of the steel used was identified as one of the failure causes, measures should be taken to prevent or mitigate embrittlement. This could involve using different materials, treatments, or design modifications.