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Technical Report PB942

FAILURE INVESTIGATION ON THE FERMI 2 LP L-1 STAGE BLADES

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EXECUTIVE SUMMARY

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A failure investigation was conducted for the LP L-1 blade root cracking in the Detroit Edison Fermi Station Unit #2. This report describes procedures, and presents the results of the investigation.

A finite element model was constructed to represent the L-1 blade [redacted]

[redacted]

[illegible]

[redacted]

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1.0 INTRODUCTION

This report describes the investigation conducted by Stress Technology Incorporated for Detroit Edison Company to determine the most likely cause of the L-1 blade root cracking in Fermi Station Unit #2. Fermi Station Unit #2 is a 1100 MW machine which was commissioned in 1988. The unit has one HP turbine and three nominally similar LP turbines. [redacted]

[redacted]

5.0 FATIGUE LIFE

1st paragraph as marked

Fatigue life prediction is based on the calculated steady and dynamic stress magnitude, and is performed using [redacted] Fatigue properties of the blading material [redacted] used in the fatigue analysis are summarized in Table 5.1.

[redacted]

[redacted]

[redacted]

[redacted]

[illegible] Disclosure

[redacted]

6.0 CONCLUSIONS

[redacted]

Finally, note that due to lack of information, it is not known as to the effect of steam enviroment in terms of corrosion fatigue and/or stress corrosion.

7.0 REFERENCES

[1] Boller, CHR. and Seeger, T., "Material Data for Cyclic Loading. Elsevier, 1987.

[2] [redacted] User's Manual, Stress Technology Incorporated.

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APPENDIX A

Life Estimation for Steam Turbine Low Pressure Blading
Local Strain Approach

[illegible]

Life Estimation for Steam Turbine Low Pressure Blading - Local Strain Approach

1.0 Damage Mechanisms

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For low-pressure steam turbine blading, some of the commonly observed causes of material damage are:

A) <u>Fatigue Related Material Damage</u> - This damage is in general a combination of the **low-cycle** fatigue (LCF) and the **high-cycle** fatigue (HCF). Which type of fatigue mode is dominant is largely case dependent, and is dictated by events [redacted]

B) <u>Corrosion Related Material Damage</u> - Corrosion can be a dominant material damage mechanism for the "Wet" or the "Wilson Line" LP stages. This is especially true for the situations where water chemistry is not within the manufacturer's specifications. Some of the typical manifestations of corrosion related material damage are **corrosion fatigue** and **stress corrosion**. [redacted]

In general any failure can be divided into three phases: 1) Crack initiation, 2) Crack propagation, and 3) Final failure. Some of the simple failure models do not attempt to separate these phases, but rather give a total time to failure. [redacted]

The material damage mechanisms mentioned above can be responsible for crack initiation as well as crack propagation phase of failures. Note that the life estimation presented here addresses crack initiation because of cyclic fatigue only, it <u>does not</u> address crack propagation.

2.0 Basics of Cyclic Fatigue

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Cyclic fatigue refers to material damage at a point in a structure resulting from alternating (cyclic) stresses. The stress state at a point may be such that there may or may not be any mean stress (completely reversed cyclic fatigue) associated with the alternating stresses.

Two types of fatigue models are generally used to estimate the life of a component under cyclic loading. First approach is a **stress based** Goodman-type fatigue model, and the other is the local-strain type strain based approach. Some of the limitations of Goodman-type approach are:

[redacted]

2) Effects of loading history can not be modelled.

[redacted]

3.0 Low-cycle Fatigue (LCF)

Low-cycle fatigue is a cyclic fatigue phenomenon where the crack initiation lives are typically between 10 and 10^5 cycles. This is a cyclic straining of a material characterized by large plastic strains. Low-cycle fatigue in steam turbines is a result of unit up-down and overspeed cycles. Generally speaking, under comparable levels of stress, a base-load unit would suffer a lesser low-cycle fatigue damage than a peak-load unit.

Low-cycle fatigue life for a material undergoing a plastic strain cycling can be represented as:

[redacted] (1)

[redacted]

4.0 High-cycle Fatigue (HCF)

By definition, high-cycle fatigue is a cyclic fatigue phenomenon where the crack initiation lives are of the order of 10^6 cycles or higher. In the case of steam turbines, the LP rotating blades if not tuned properly, can operate in or near resonance in one or more modes of vibration and can accumulate a very large number of stress cycles. For example, a blade group vibrating at 300 Hz. accumulates 1.10^{10} cycles in a year of continuous operation. If the stress amplitudes are of sufficient strength, a high-cycle fatigue failure can result. High-cycle fatigue life for a material undergoing an elastic strain cycling can be represented as:

[redacted] (2)

[redacted]

[redacted]

5.0 Strain-Life Relation

The total strain amplitude at a point is defined as summation of the elastic and the plastic strain amplitudes. Thus,

[redacted] (3)

[redacted] (4)

[redacted] More information on the local strain approach can be found in [1,2].

Reference

1) H. O. Fuchs & R. I. Stephens, "Metals Fatigue in Engineering", John Wiley & Sons, 1980

2) Bannantine, J. A., Comer, J. J., Handrock J. L., "Fundamental of Metal Fatigue Analysis", Prentice Hall, 1990

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APPENDIX B

Wheel Diagram of the L-1 Blades that Had Cracked Blades