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CALCULATION TITLE PAGE

Client: Public Service Electric & Gas	PAGE 1 OF 9
Project: Salem EDG Liner Cracking	TASK NO.: 108-32
Calculation Title: Fatigue Evaluation	CALCULATION NO.: 108-32-02

REVISION NO.	PAGE NO. AFFECTED	PREPARER(S)/ DATE	CHECKER(S)/ DATE	REVIEWER(S)/ DATE
0		12/17/93	12/23/93	12/23/93

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RECORD OF REVISIONS

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Revision	Description
ϕ	Initial Issue

1.0 PURPOSE

The purpose of this calculation is to evaluate the possibility of fatigue cracks developing in ALCO 251 diesel engine cylinder liners due to mechanical loads.

2.0 RESULTS

Several cases were evaluated: the nominal configuration along with several other cases to evaluate variations in key parameters. The table below summarizes the calculated alternating stresses and the mean-stress adjusted endurance limit for each case.

Case	Mean Stress (ksi)	Alternating Stress (ksi)	Goodman Diagram Endurance Limit (ksi)		Eliptic Rule Endurance Limit (ksi)	
			σ_u=36	σ_u=42	σ_u=36	σ_u=42
Nominal	27.1	7.6	4.5	6.4	11.8	13.8
2 Mil Offset	29.3	7.6	3.4	5.4	10.5	12.9
8 Mil Offset	34.7	8.9	0.7	3.1	4.8	10.1
Worst Case	36.8	9.4	0	2.2	0	8.7

3.0 CALCULATION

The maximum stresses in the cylinder liner due to bolt preload forces and the engine firing pressure occur at the relief groove, at a location about 45° from the top of the groove. This location is shown in Figure 1. The stress intensity at this location was calculated in Reference 1 for several fit-up/tolerance cases (these cases are discussed in more detail in Reference 1):

- Nominal - The nominal liner tolerances along with essentially no liner flange/engine block misalignment.
- 2 Mil Offset - The nominal liner tolerances along with 2 mils of misalignment between the liner flange and engine block.

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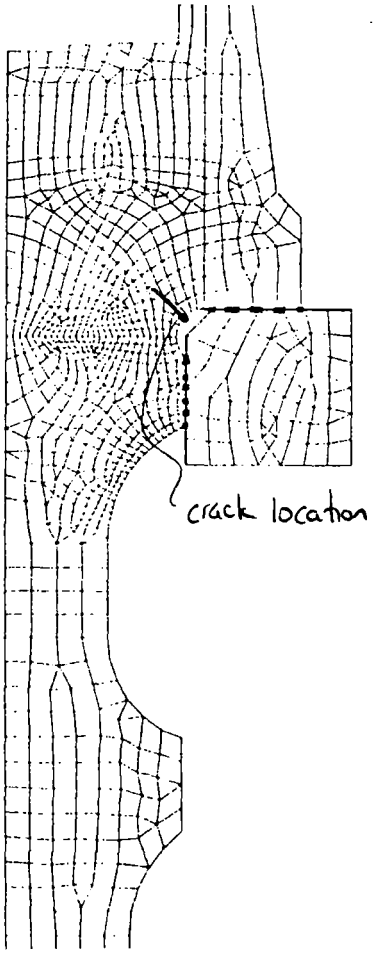


Figure 1

- 8 Mil Offset - The nominal liner tolerances along with 8 mils of misalignment between the liner flange and engine block.
- Worst Case - The worst case (from a stress point of view) tolerances along with the 8 mils misalignment.

Further, stresses were calculated for two conditions for each case: engine firing and not firing. These two conditions represent the mechanical stress cycle for the liner.

The engine firing is a high cycle load (about 450 cycles per minute) so the mean stress endurance limit will be determined for comparison to the calculated stress intensities. From Reference 1, the calculated stress intensities are:

Case	Maximum Stress Intensity (ksi)	Minimum Stress Intensity (ksi)	Alternating Stress Intensity (ksi)
Nominal	34.6	19.5	7.6
2 Mil Offset	36.9	21.7	7.6
8 Mil Offset	43.6	25.7	8.9
Worst Case	46.2	27.3	9.4

The maximum stress intensity occurs during liner/head fit-up; the minimum stress intensity occurs during engine firing. The alternating stress intensity is one-half the peak-to-peak range.

The endurance limit is a function of the mean stress intensity during the cycle. As the mean stress intensity increases, the endurance limit decreases. Two common methods for accounting for this effect are the Goodman Diagram and the Eliptic Rule. The Goodman Diagram is described by:

$$\frac{\sigma_a}{\sigma_n} + \frac{\sigma_m}{\sigma_u} = 1$$

where σ_a is the endurance limit for a mean stress of σ_m, σ_n is the endurance limit with zero mean stress, and σ_u is the material tensile strength. The Eliptic Rule is described by:

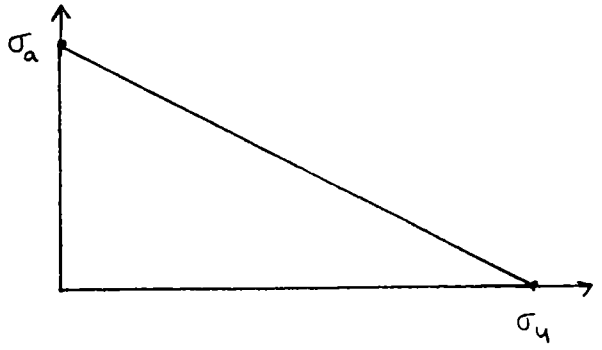
$$\left[\frac{\sigma_a}{\sigma_n}\right]^2 + \left[\frac{\sigma_m}{\sigma_u}\right]^2 = 1$$

These relationships are shown graphically on the following page.

The specified material minimum tensile strength is 36 ksi (Reference 2). However, tensile tests show the tensile strength to be as high as 42 ksi. As a result, all calculations will be perfromed for both the 36 and 42 ksi values.

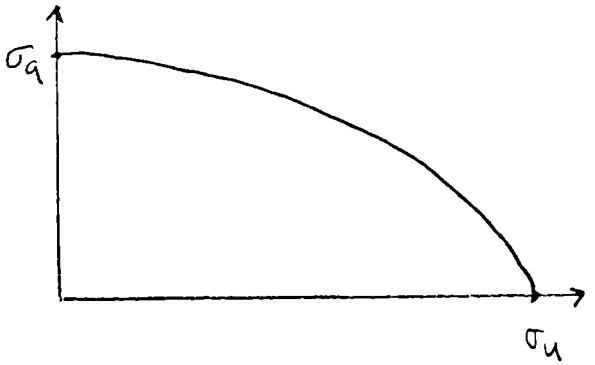
The zero mean stress endurance limit for cast iron varies depending on chemistry, strength and environment from about 15 to 22 ksi (it is typically about one-half the tensile strength). For the cylinder liners, an endurance limit of 18 ksi will be used (one-half the specified minimum tensile strength). Figure 2 shows a typical fatigue curve for cast iron. This curve shows an endurance limit of about 20 ksi.

Using the above stresses and material properties, the mean stress adjusted endurance limits are calculated and are shown in Section 2.



Goodman Diagram

$$\frac{\sigma_n}{\sigma_a} + \frac{\sigma_m}{\sigma_u} = 1$$



$$\left(\frac{\sigma_n}{\sigma_a}\right)^2 + \left(\frac{\sigma_m}{\sigma_u}\right)^2 = 1$$

Eliptic Rule

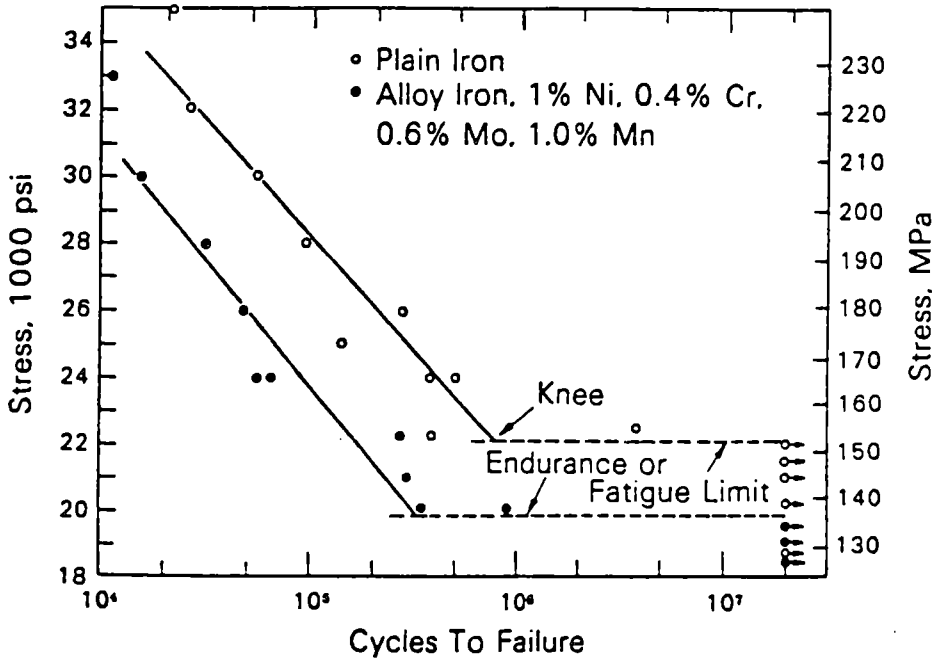


Figure 2
(Reference 3)

4.0 REFERENCES

1. MPR Calculation 108-32-01, "Finite Element Stress Analysis", 12/17/93.

2. Alco Power Co., Specification for Cast Iron Cylinder Liners.

3. Atlas of Fatigue Curves, American Society for Metals, 1986.