MAE 672
Stress Analysis in Design

Heart Valve Stent

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1 Abstract

A heart valve stent is subjected to many cycles of stress in the linear region. Potential crack growth and fatigue is analyzed under these conditions and a maximum allowable crack size is calculated to be .0073 in for flat plate cracking and .00505 for corner cracking. Under these conditions an indefinite service life is possible.

2 Introduction

A heart valve sent goes through a stress cycle for every heart beat. This is simulated with a .060 in radially inward displacement of the tip of the stent. The stent is a circular item with 120° circular symetry. Only one third is shown in Figure 1.

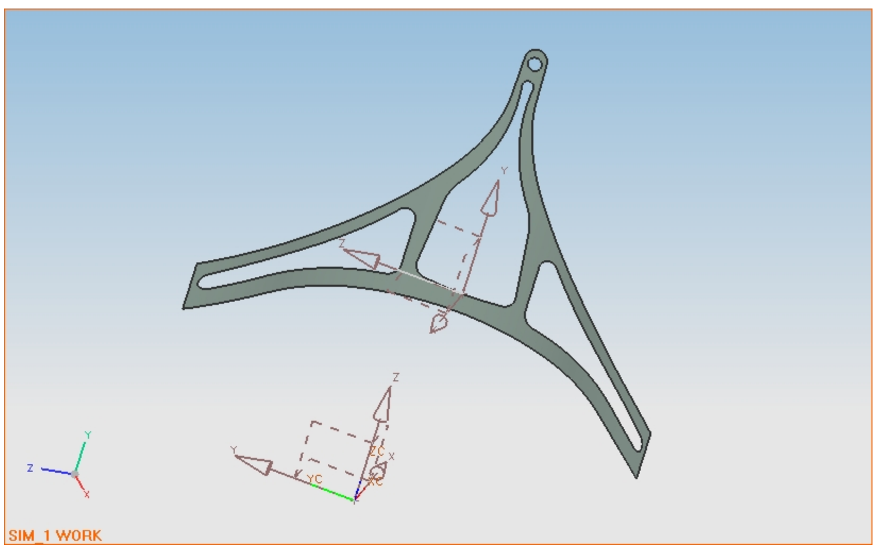

Figure 1: 1/3 Stent

Flat plate surface cracking and corner cracking are evaluated for maxiumum allowable crack size.

Table 1 contains the material data. Nastran finite element anlysis software was used with Unigraphics NX as a pre and post processor.

Table 1: Material Properties

Modulus of Elasticity E and Poisons Ratio ν		
E	15.8(10E6	
ν	0.31	
Facture Toughness (ksi sqrt(in))		
	Mean	B allowable
K (ksi$\sqrt{\text{in}}$)	96	88
ΔK_{th} (ksi$\sqrt{\text{in}}$)	3.89	3.4
Fracture Toughness Limit on Linear		
K_{lin} (ksi$\sqrt{\text{in}}$)	100	

3 Procedure

3.1 Finite Element Analysis

Nastran Finite Element Analyisis was used to model the displacement and stresses. The stent has circular symetry Figure 2 shows one third of the actual stent with the constraints.

The model was constrained with respect to a cylindrical coordinate system located at the center of curvature with the Z axis parallel to axis of symetry. The ends were fixed in translation in the θ and bottom corners in the Z direction. The lower ends were also fixed in rotation about the θ and z axis. The top, as shown was constrained in dispalcement in the r direction by .060 in.

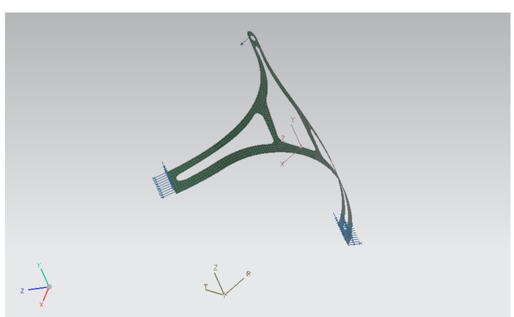

Figure 2: Constraints

3.2 Surface and Corner Crack Analysis

Crack growth is checked for stability and to see if it will grow in the longitudinal direction or the radial direction. Figure 3 illustrates the a, c and angle ϕ dimensions for the surface crack and 4 for the corner crack case. Standard forumulas for K_I were used [1, Appendix 9].

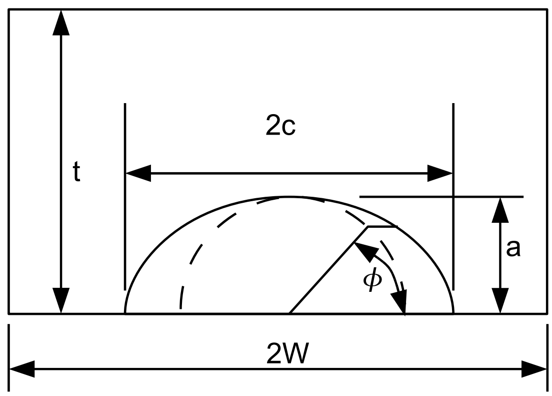

Figure 3: Wall Crack Cross Section

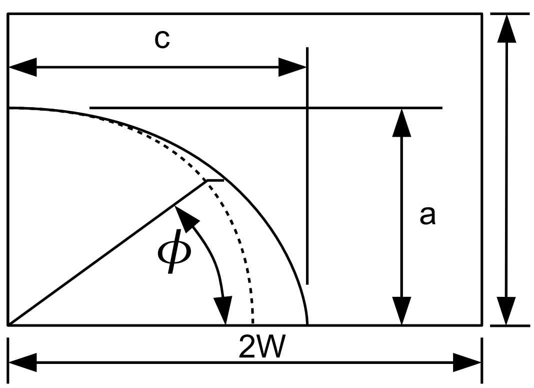

Figure 4: corner Crack Cross Section

The stress v.s. crack length is plotted for a constant K_{IC} for $\phi =$ 90(crack growth into the material) and $\phi = 0$ (crack growth in a direction along the surface).This was evaluated up to a crack length up to (0.008 in).

The ΔK_{th} was used since it is the lowest value of K_I where failure is expected to occure and the part is stressed many times.

3.3 Failure Analysis

The failure analysis involves a plot of stress intensity K v.s. crack lenght a. The critical fracture resistance are values for ΔK_{th} horizontal lines. Failure is indicated for points above the ΔK_{th}.

4 Results

4.1 Finite Element Analysis

Comparing figures 5 and 6 it can be seen the the maximum princple stress is 38.55 ksi.

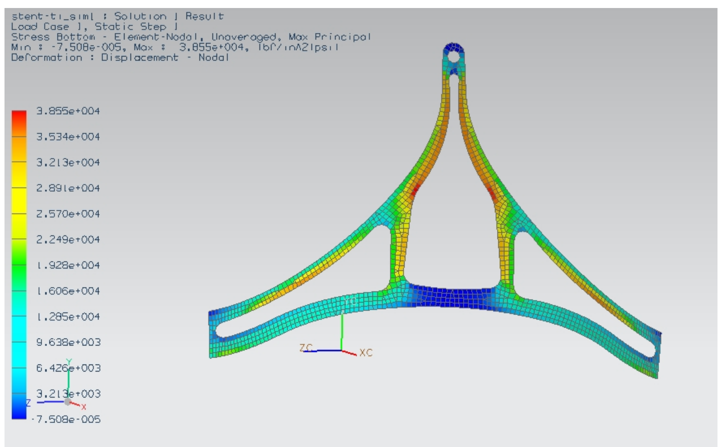

Figure 5: Maximum Principle Stress on Inside

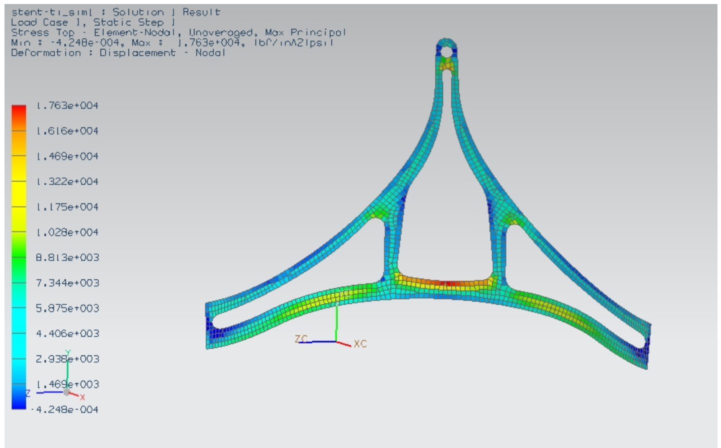

Figure 6: Maximum Principle Stress on Inside

4.2 Maximum Allowable Crack size

Figure 7 shows that the the critical K_I is reached at 0.00505 in for a corner crack where $\phi = 0°$ and .00603 in where $\phi = 0$ with a semi elliptical crack. Thus the maximum allowable crack size is 0.0055 in for a corner crack and .00603 in for a semi elliptical surface crack.

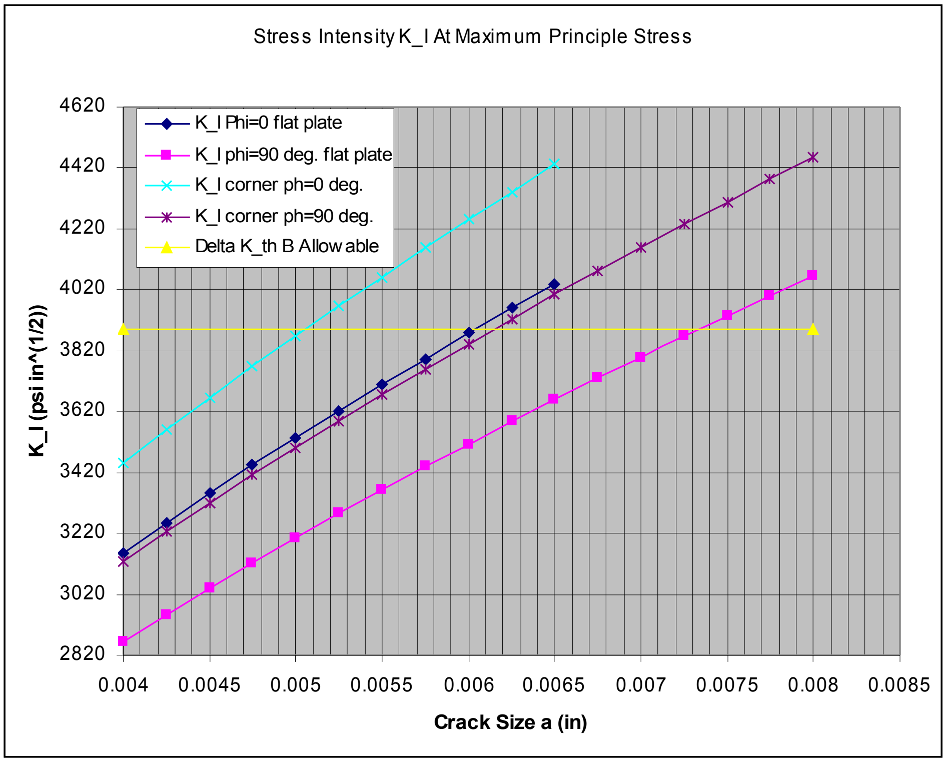

Figure 7: K_I v.s. Crack length and ΔK_{th} Maximum Principle Stress

5 Discussion

A failure analysis vs crack resistance diagram is not used because the stent is not stressed in the yielding range. The only critical fracture crack size coresponds to b allowable ΔK_{th} because as illustrated in figure 8 the fracture resistance values other than b allowable are higher, in some case much higher and so if failure occurs, it will be at the b allowable Δk_{th} value.

Under these conditions an infinite service life appears to be possible but may not be necessary since a finite service life may outlast a resonable life expectancy of the patient. Designing for a finite service life would require fatige data that was not available for this report.

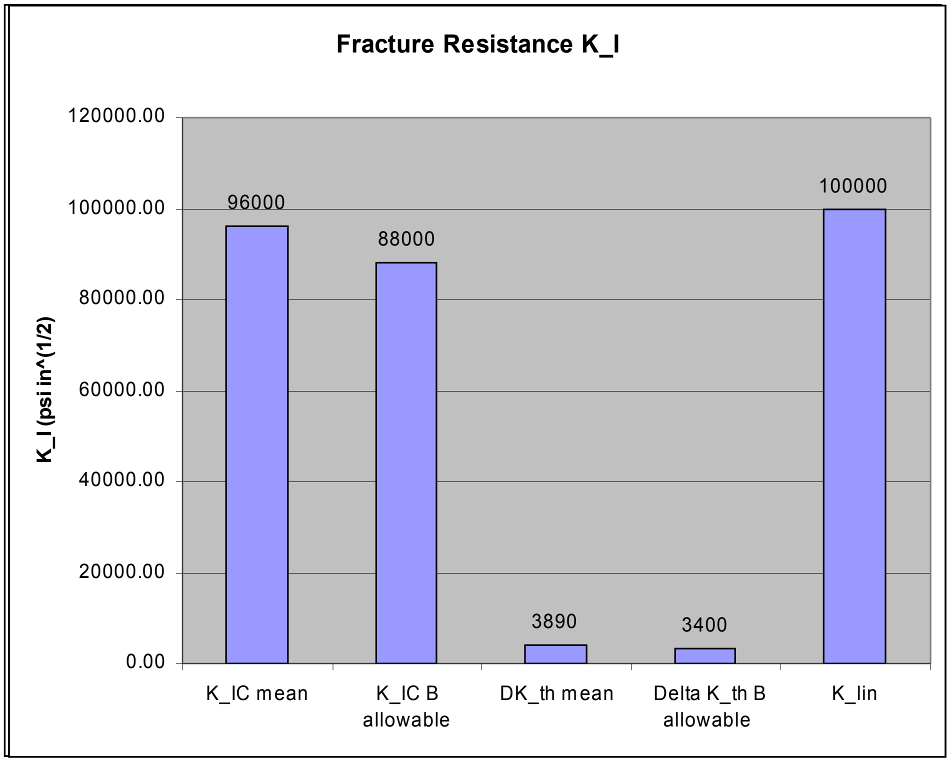

Figure 8: Comparison of ΔK_I values

6 Conclusions

The Maximum allowable crack length is .0073 in for flat plate cracking and .00505 for corner cracking. Under these conditions an indefinite service life is possible.

References

[1] T.L. Anderson *Fracture Mechanics Fundamentals and Applications*