CHAPTER 4

RESULT AND DISCUSSION

4.1 Empirical calculation

<u>Example of calculation</u>

When *a* = 0.0225m, *W* = 0.05m, *B* = 0.025m

$$0.45 \leq \frac{a}{W} \leq 0.55$$

$$\frac{a}{W} = \frac{0.0225}{0.05} = 0.45$$

Based on the requirement as stated in equation 2.11, value of length of the crack, *a* and width, *W* is valid.

$$f(\frac{a}{W}) = \left(2 + \frac{a}{W}\right)\left[0.866 + 4.64\frac{a}{W} - 13.32\frac{a^2}{W} + 14.72\frac{a^3}{W} - 5.6\frac{a^4}{W}\right]$$

$$= 8.34$$

$$\mathrm{K} = \frac{\mathrm{P}}{\mathrm{B}\sqrt{\mathrm{W}}} \cdot f\frac{a}{W}$$

When load applied, *P* =10000N

$$K = \frac{10000 \times 8.34}{0.025\sqrt{0.05}}$$

$$\boldsymbol{= 14.92\ MPa.\sqrt{m}}$$

This empirical calculation will be proceed by varying $\frac{a}{W}$ ratio from 0.45 to 0.55 for each value of thickness, B and $\frac{W}{B}$ ratio from 2.0 to 4.0 as stated in equation 2.11 and 2.12. Further result had tabulated in appendix 3.

4.2 Numerical method

In numerical method, the author had used Finite Element Analysis software (ANSYS) to investigate stress intensity factor for compact tension specimen by using KCALC command. The result had tabulated in appendix 3.

4.3 Comparing empirical calculation and numerical method

This section is the important part of this project since the objectives of this project are to gather and compare value of stress intensity factor from empirical calculation and numerical method in graphs so that users can interpret the value easily. These graphs had plotted to help users to find stress intensity factor for various crack length, thickness and width. Load that been applied is 1000N and width of the specimen is constantly 0.05 meter. The author had accomplished to plot two types of graphs which are:

a) Graph of stress intensity factor versus $\frac{W}{B}$ ratio for $0.45 \leq \frac{a}{W} \leq 0.55$ are show by figures 4.1 and 4.2
b) Graph of stress intensity factor versus $\frac{a}{W}$ ratio for $2.0 \leq \frac{W}{B} \leq 4.0$ are show by figures 4.3, 4.4, 4.5 and 4.6

To interpret stress intensity factor for each ratio from the graphs, the author had indicate:

a) Stress intensity factor for empirical calculation by straight line
b) Stress intensity factor for numerical method by dash line
c) Empirical calculation and numerical method for the same ratio indicated by the same color

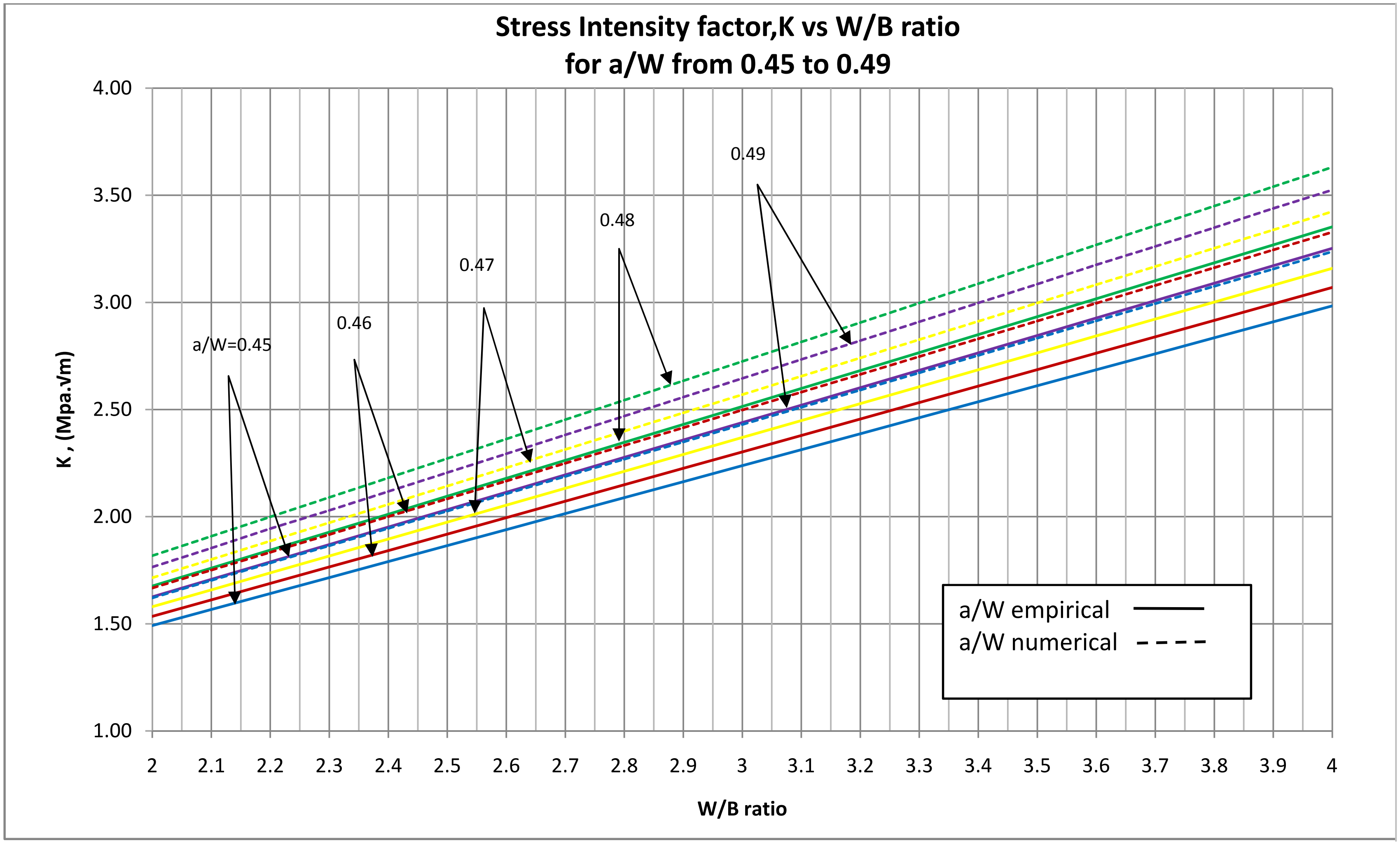

Figure 4.1: Graph of Stress Intensity Factor versus $\frac{W}{B}$ for CTS at P =1000N

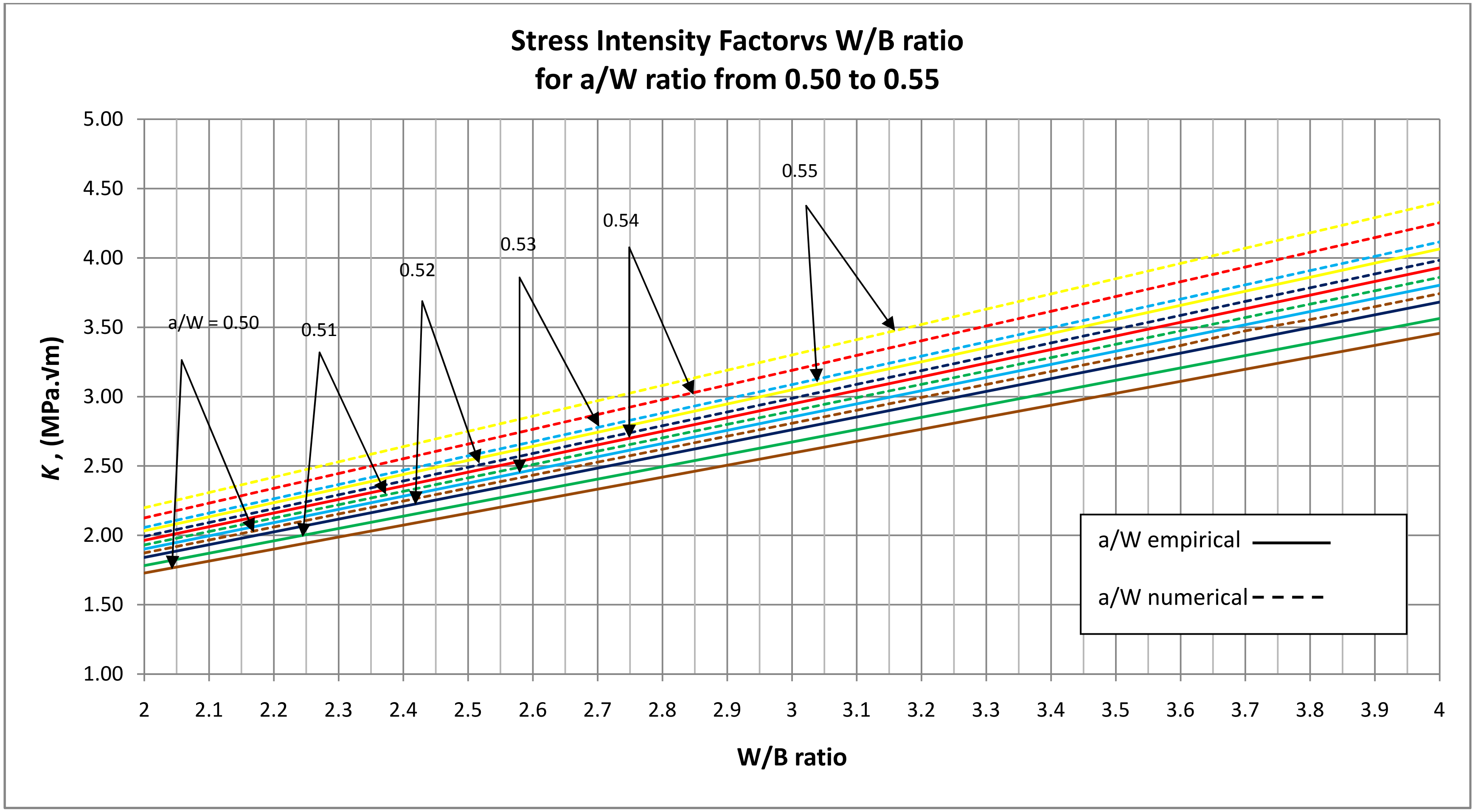

Figure 4.2: Graph of Stress Intensity Factor versus $\frac{W}{B}$ ratio for CTS at P =1000N

DISSCUSSION:

From figure 4.1 and 4.2, the author can interpret that:

a) Graphs are linear
b) Stress intensity factor is proportional with $\frac{W}{B}$ ratio. Increment of $\frac{W}{B}$ ratio cause increment stress intensity factor
c) Stress intensity factor proportional with $\frac{a}{W}$ ratio. Increment of $\frac{a}{W}$ ratio cause increment stress intensity factor
d) Numerical method generate higher stress intensity factor than empirical calculation
e) Both of the graphs are agree with equation 2.8

The interpretations above are related with the effect of thickness, width and crack length to stress intensity factor. Increasing of thickness can cause decreasing of stress intensity factor because the higher the thickness the higher the resistance for specimen to fracture. So, specimen is remote from failure. This concept is contrary with the term $\frac{W}{B}$ ratio that will produce increasing of stress intensity factor.

Furthermore, increment of crack length also will cause increment in stress intensity factor. The reason for this because of the stress at the crack tip is higher if the crack length is higher. Higher stress at the crack tip will lead to higher stress intensity factor.

The best approach to determine types of graphs that can give the most accurate value of stress intensity factor is by finding percentage different or agreement between empirical calculation and numerical method. Both of these methods had been compare and tabulated in the table 4.1. Numerical method generated higher stress intensity factor than empirical calculation. Referred to table 4.1, the author can interpret that numerical method and empirical calculation have good agreement. This can be proved by small percentage different with average 8.67%.

Table 4.1: Comparing Stress Intensity Factor for empirical and numerical method for

$$\frac{a}{W} = 0.45$$

Load (N)	Crack length, a (m)	Thickness, B (m)	Width, W (m)	Stress Intensity Factor (MPa.√m) Empirical	Numerical	Percentage different (%)
1000	0.0225	0.0250	0.050	1.492	1.621	8.65
1000	0.0225	0.0238	0.050	1.567	1.703	8.69
1000	0.0225	0.0227	0.050	1.641	1.784	8.68
1000	0.0225	0.0217	0.050	1.716	1.864	8.67

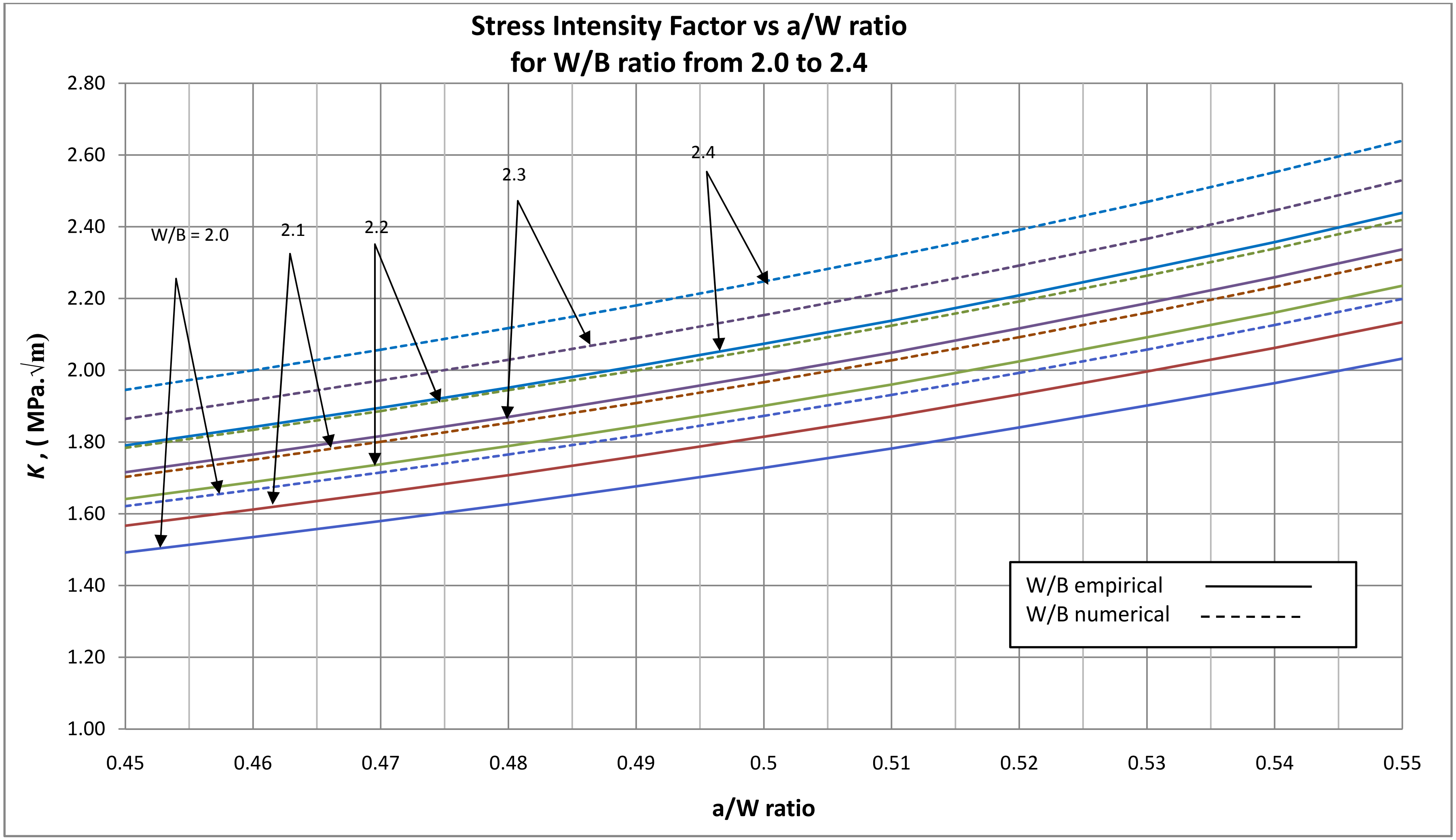

Figure 4.3: Stress Intensity Factor versus $\frac{a}{W}$ ratio for CTS at P =1000N

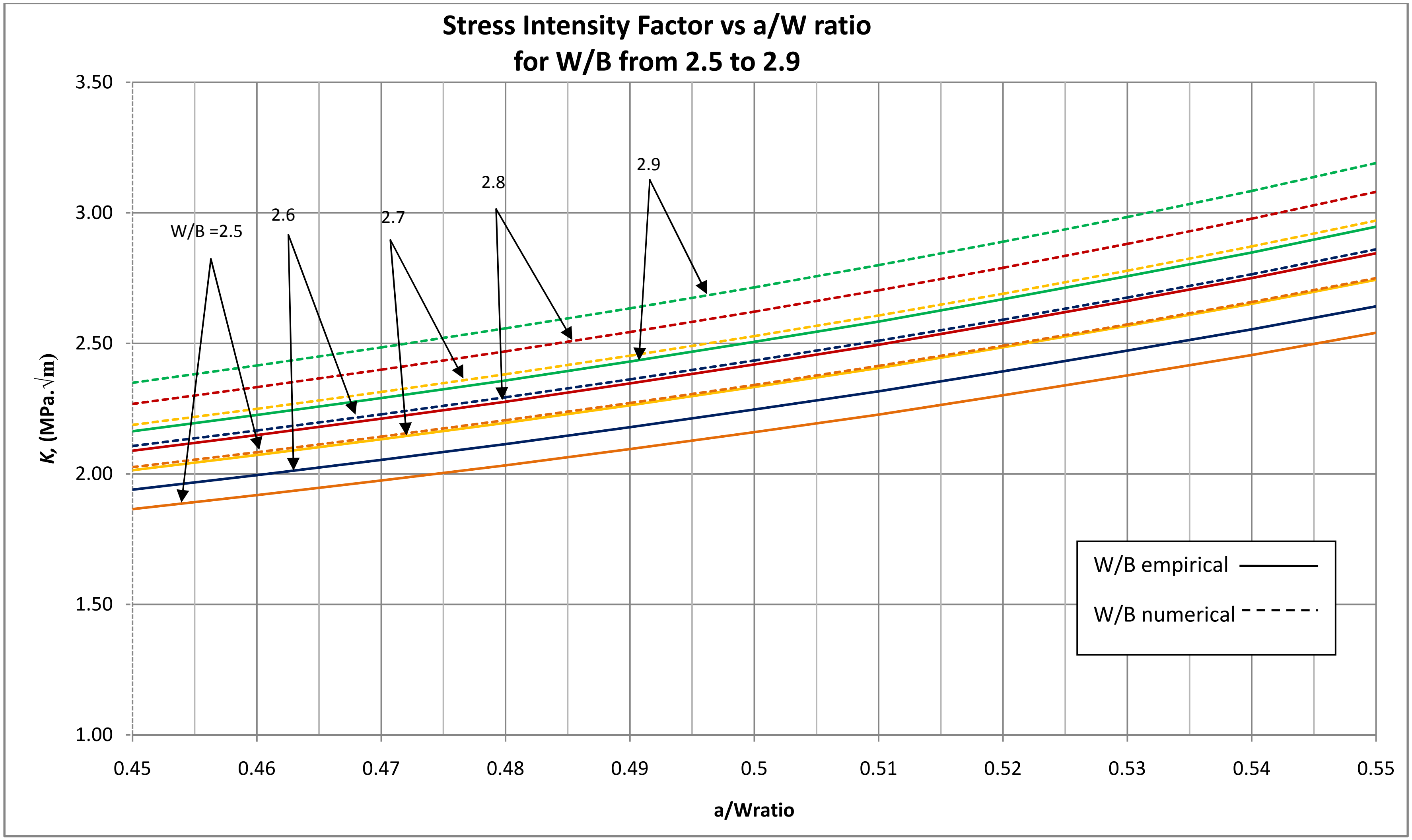

Figure 4.4: Stress Intensity Factor versus $\frac{a}{W}$ ratio for CTS at P =1000N

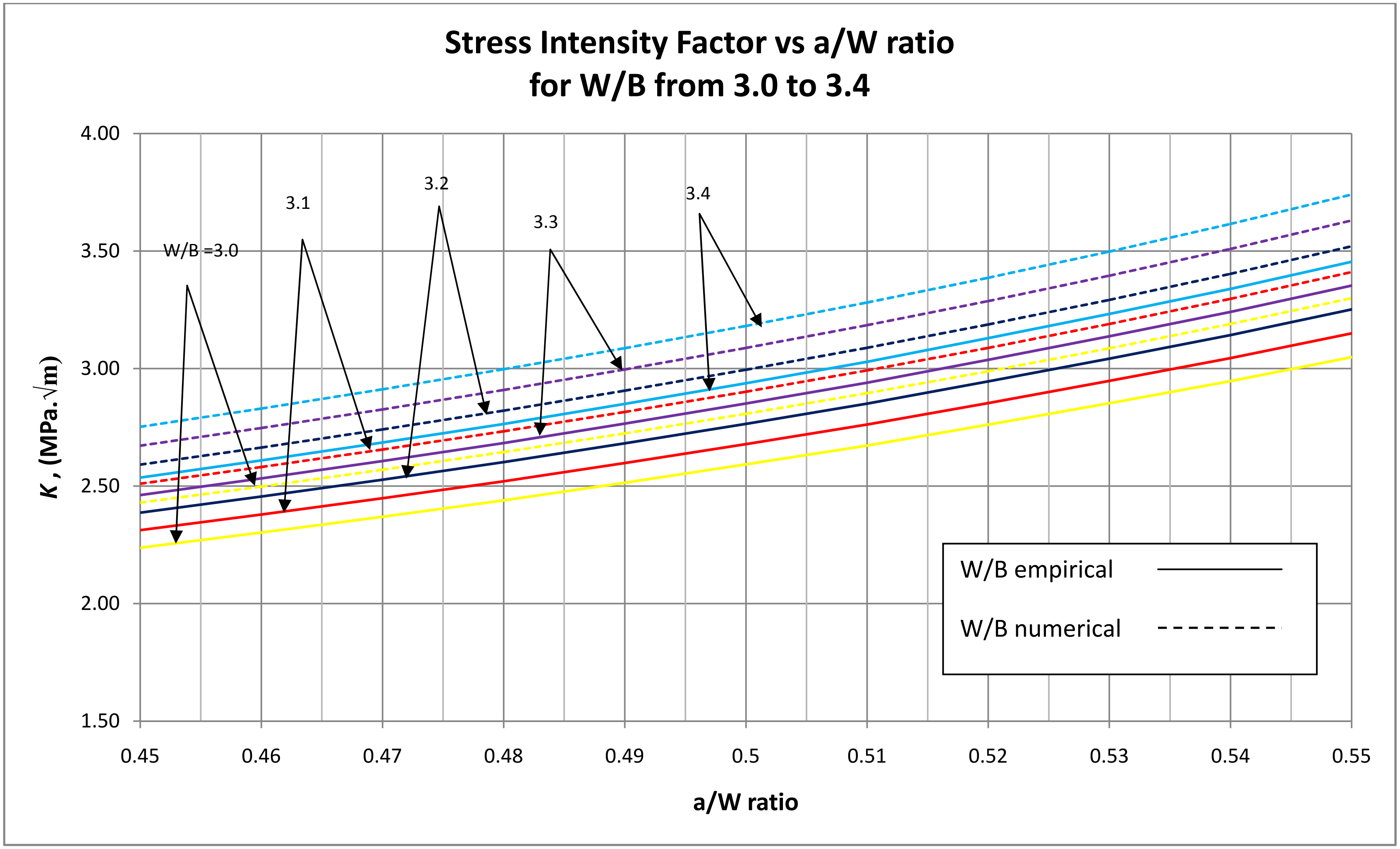

Figure 4.5: Stress Intensity Factor versus $\frac{a}{W}$ ratio for CTS at P =1000N

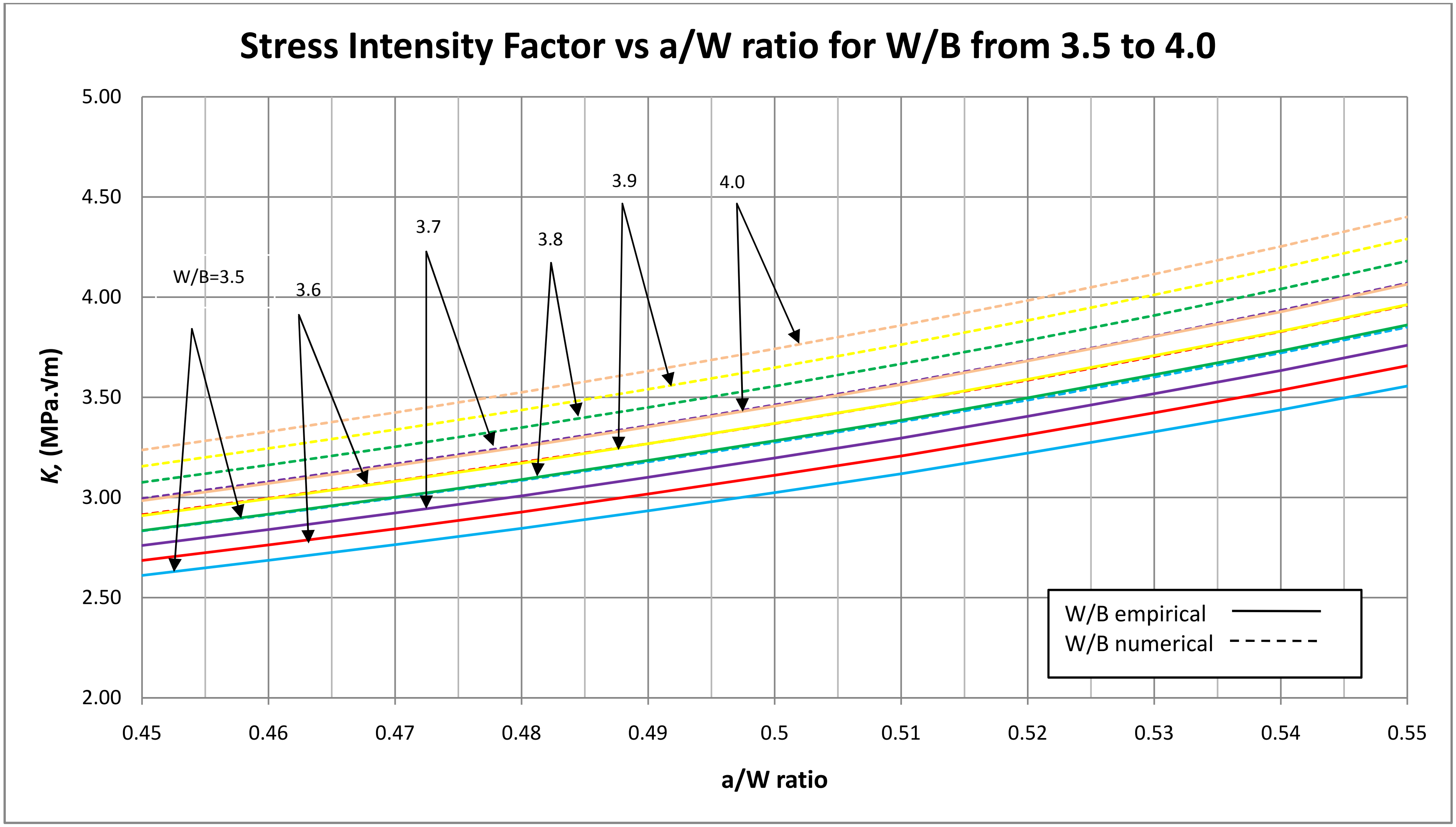

Figure 4.6: Stress Intensity Factor versus $\frac{a}{W}$ ratio for CTS at P =1000N

DISCUSSION:

From figure 4.3, 4.4, 4.5 and 4.6, the author can interpret that:

a) Graphs are linear
b) Stress intensity factor is proportional with $\frac{a}{W}$ ratio. Increment of $\frac{a}{W}$ ratio cause increment stress intensity factor
c) Stress intensity factor proportional with $\frac{W}{B}$ ratio. Increment of $\frac{W}{B}$ ratio cause increment stress intensity factor
d) Numerical method generate higher stress intensity factor than empirical calculation
e) All of the graphs are agree with equation 2.8

The interpretations above are related with the effect of thickness, width and crack length to stress intensity factor. Increment of crack length also will cause increment in stress intensity factor. The reason for this because of the stress at the crack tip is higher if the crack length is higher. Higher stress at the crack tip will lead to higher stress intensity factor. While increased of thickness can cause decreased of stress intensity factor because the higher the thickness the higher the resistance for specimen to fracture. So, specimen is remote from failure. This concept is contrary with the term $\frac{W}{B}$ ratio that will produce increment of stress intensity factor.

The best approach to determine types of graphs that can give the most accurate value of stress intensity factor is by finding percentage different between empirical calculation and numerical method. Both of these methods had been compare and tabulated in the table 4.4. Numerical method had generated higher stress intensity factor than empirical calculation. Referred to table 4.2, the author can interpret that numerical method and empirical calculation have good agreement. This can be proved by small percentage different with average 8.58%.

Table 4.2: Comparing Stress Intensity Factor for Empirical and Numerical method for $\frac{W}{B} = 2.0$

				Stress Intensity Factor (MPa.√m)		
Load (N)	Crack length,a (m)	Thickness,B (m)	Width,W (m)	Empirical	Numerical	Percentage error (%)
1000	0.0225	0.0250	0.050	1.492	1.621	8.65
1000	0.0230	0.0250	0.050	1.535	1.667	8.60
1000	0.0235	0.0250	0.050	1.580	1.715	8.54
1000	0.0240	0.0250	0.050	1.626	1.765	8.54

Both types of graphs produce the almost the same percentage difference. So, both of them have the same efficiency.

4.4 STRESS INTENSITY FACTOR FOR OTHER APPLIED LOADS

To prove that figures 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6 is valid for any load that been applied to compact tension specimen, graph of stress intensity factor versus load had been made. Figure 4.7 shows that stress intensity factor for empirical calculation and numerical method is proportional to the load applied. To validate this graph, data of the graph has been tabulate at table 4.3.

Table 4.3: Validate data from graph Stress Intensity Factor versus Load

	Stress Intensity Factor (MPa.√m)		
Load (N)	Empirical	Numerical	Percentage error (%)
1000	1.658	1.622	2.17
2000	3.316	3.244	2.17
3000	4.974	4.866	2.17
4000	6.632	6.488	2.18

Example of calculation for numerical method

When P = 2000 N;

$$K = 1.622 \times 2 = 3.244 \ \text{Mpa}\sqrt{m}$$

When P = 3000 N;

$$K = 1.622 \times 3 = 4.866 \ \text{Mpa}\sqrt{m}$$

When P = 4000 N;

$$K = 1.622 \times 4 = 6.488 \ \text{Mpa}\sqrt{m}$$

From the simple calculation, the graphs are applicable for other load instead of 1000 N because of the consistent increment of stress intensity factor for compact tension specimen with load. To use figure 4.1 to 4.6 for other load, users only have to multiply stress intensity factor with suitable increment but all of variables must still in limit of validity as stated in equation 2.10, 2.11 and 2.12.

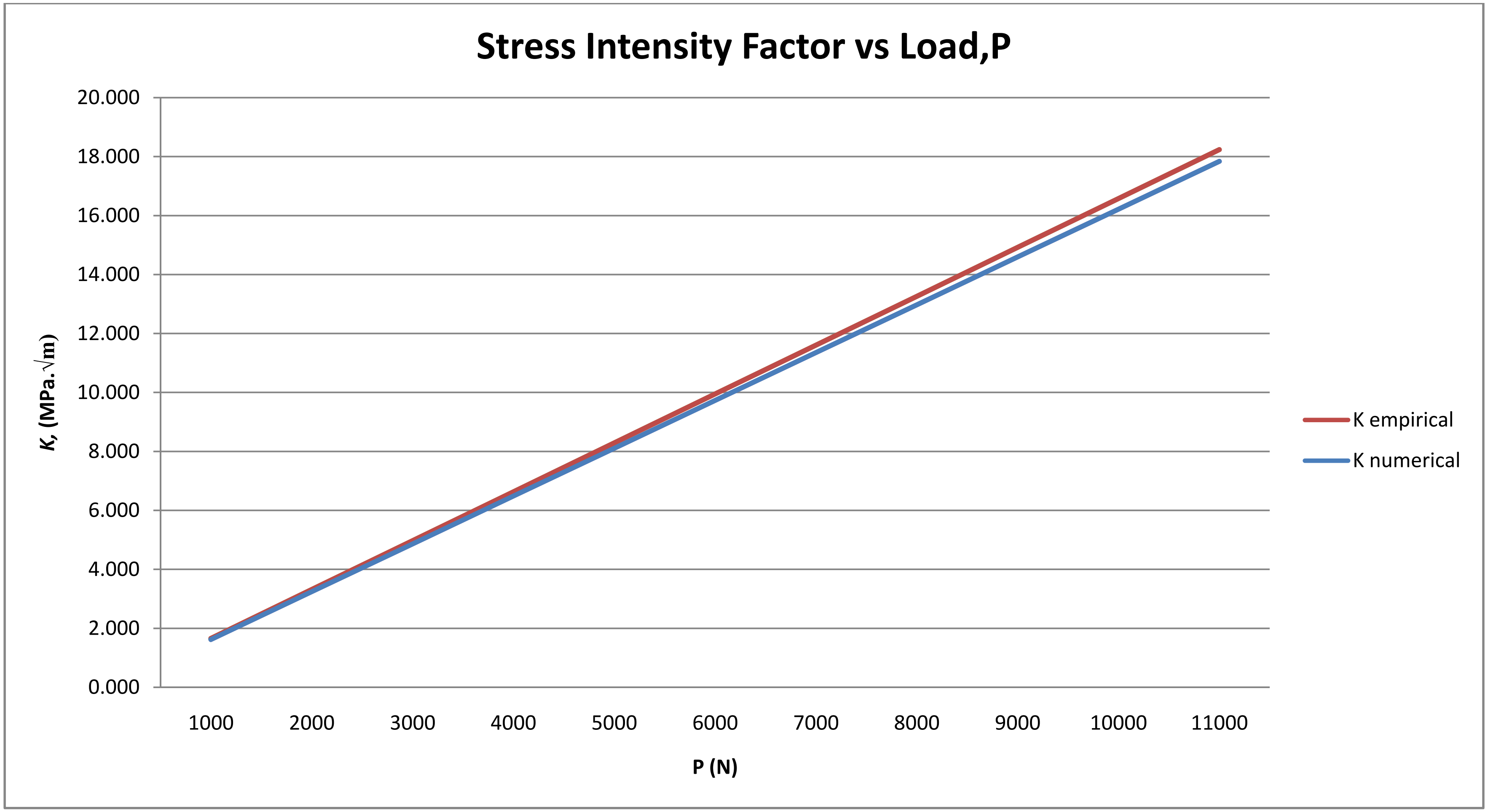

Figure 4.7: Graph of Stress Intensity Factor versus load for $\frac{a}{W}$ = 0.45 and $\frac{W}{B}$ = 2.0