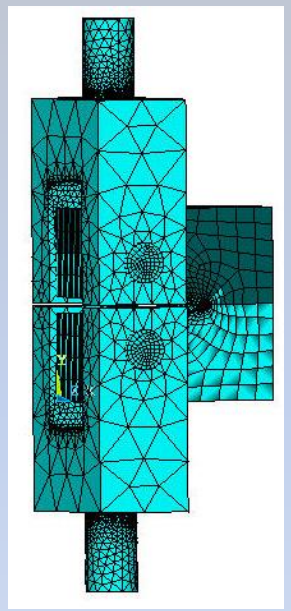
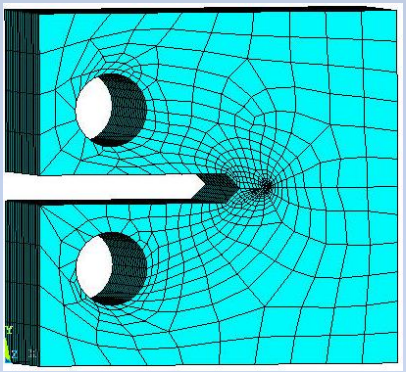
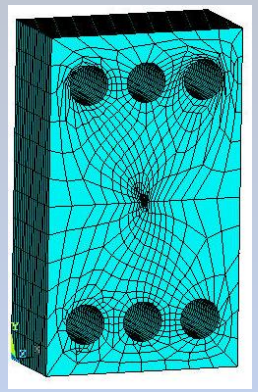
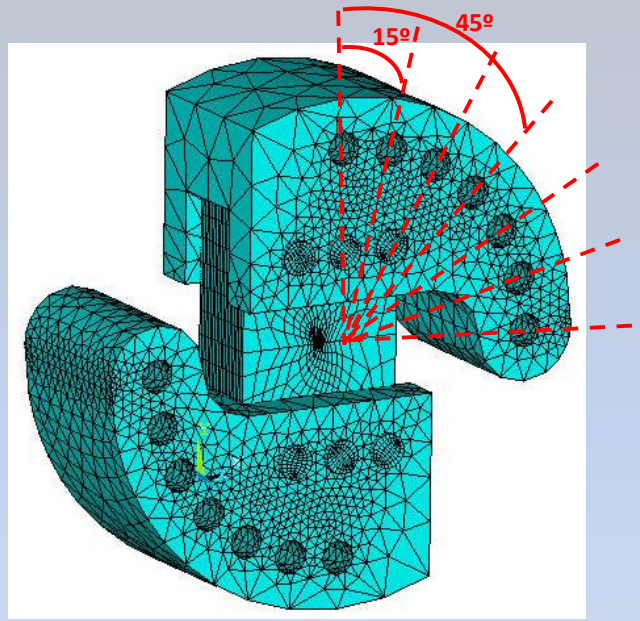
Three-Dimensional Fracture Analyses of Compact Tension Shear Specimen Under In-Plane Mixed Mode Loading









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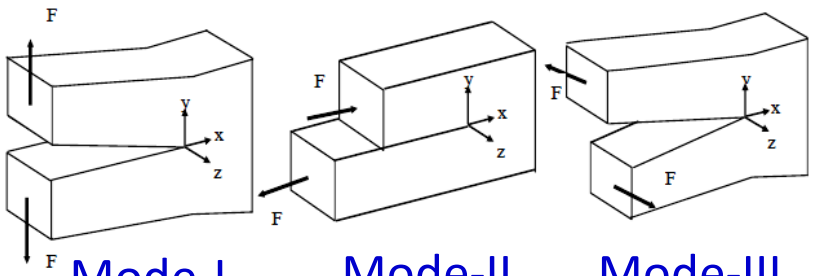
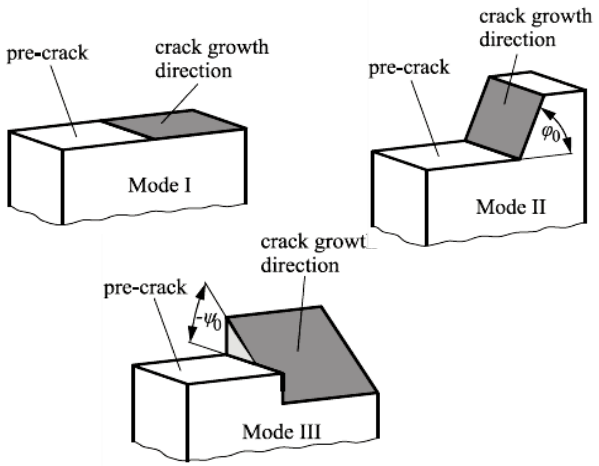
Outline

- Motivation
- Materials and Method
- Numerical Studies
  - Comparison and Validation of FRAC3D Results
  - Load Linearity Test Analyses
  - Loading and Boundary Condition Sensitivity Analyses
  - Contact Type and Boundary Condition Sensitivity Analyses
  - Friction Coefficient Sensitivity Analyses
- Summary and Conclusions

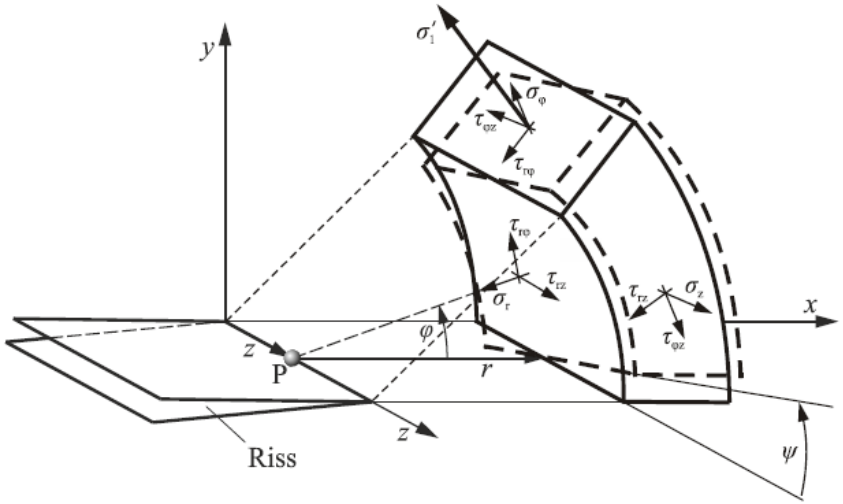
Motivation



The three basic modes of crack extension



Crack propagation profiles under different modes



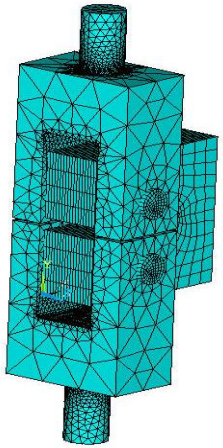
Mixed-mode experimental studies exist in literature applied by Richard et al.

Combinations of modes (**mixed-mode loading)** are also possible.

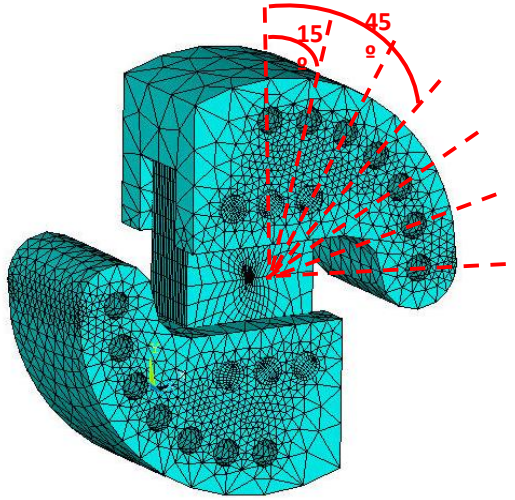
***Ref [1] :** Richard, H. A., Schirmeisen N. H., Eberlein, A.," Experimental investigations on mixed-mode-loaded cracks ".

Materials and Method

- Geometric and finite element models used in this study are generated by ANSYS™
- Modeling, meshing, defining loads, boundary conditions and contacts and the solution of the problem involving the whole assembly, i.e., loading devices, pins and the specimen, with contact mechanics are performed using ANSYS™
- Stress intensity factors are computed using FRAC3D, a general-purpose finite element based 3-D fracture analysis program



Compact tension specimen (CT) and clevis (according to ASTM E399



Compact tension shear specimen (CTS) and mode I/II mixed-mode clevis

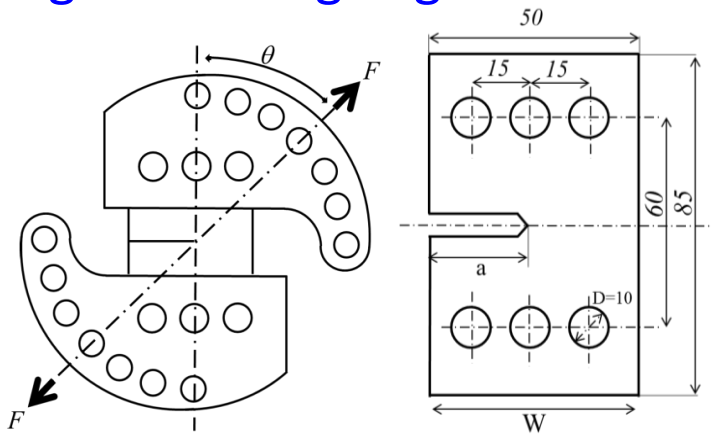
Numerical Studies

Comparison and Validation of FRAC3D Results

Fracture analyses are performed firstly using compact tension shear (CTS) specimen under in-plane mixed mode loading .

Computed stress intensity factors along the crack front are compared with empirical formula developed by Richard and numerical simulation results performed by Zhao and Guo to validate the results.

Analysis are performed and compared for 10 kN load value and 15 and 45 degree loading angles.



Geometrical parameters of CTS specimen (W=50 mm and B=10 mm)

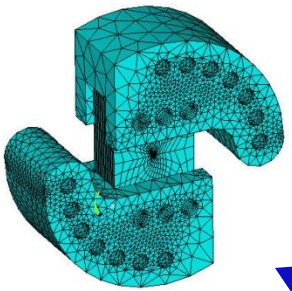
Empirical formula developed by Richard;

$$K_I = \frac{F}{wt}\sqrt{\pi a}\frac{\cos\alpha}{1-\left(\frac{a}{w}\right)}\sqrt{\frac{0.26+2.65\left(\frac{a}{(w-a)}\right)}{1+0.55\left(\frac{a}{(w-a)}\right)-0.08\left(\frac{a}{(w-a)}\right)^2}}$$

$$K_{II} = \frac{F}{wt}\sqrt{\pi a}\frac{\sin\alpha}{1-\left(\frac{a}{w}\right)}\sqrt{\frac{-0.23+1.40\left(\frac{a}{(w-a)}\right)}{1+0.67\left(\frac{a}{(w-a)}\right)-2.08\left(\frac{a}{(w-a)}\right)^2}}$$

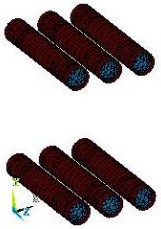
***Ref [2] :** Zhao, J., Guo, W.," Three-parameter K–T–Tz characterization of the crack-tip fields in compact-tension-shear specimens", Engineering Fracture Mechanics 92, 72–88, 2012.

Process Map

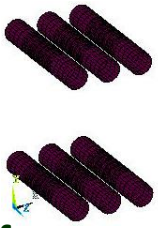


Contacts Defining

pin and holder interference

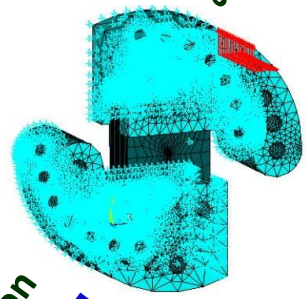


pin and specimen interference

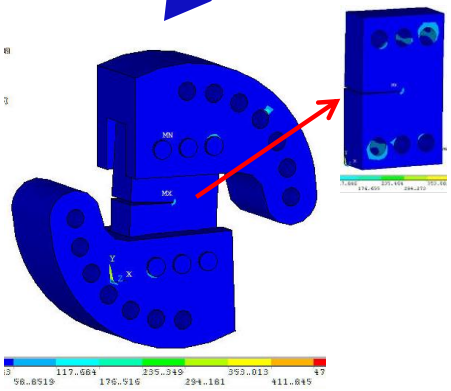


Contact&Target Surfaces

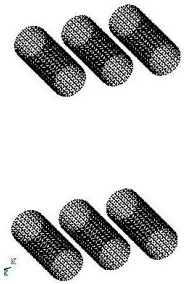
Apply Boundary Conditions and Loads



Solution



Sub-model BC's from ANSYS

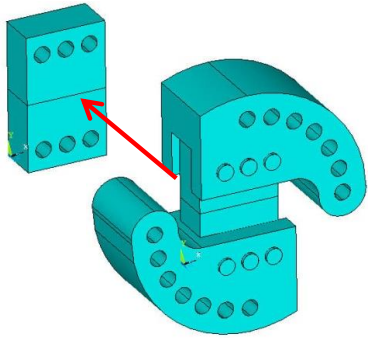


*.elis
*.nlis
*.dlis
*.crelems
*.crnodes

FRAC3D

Stress Intensity Factors (SIFs) along the crack front

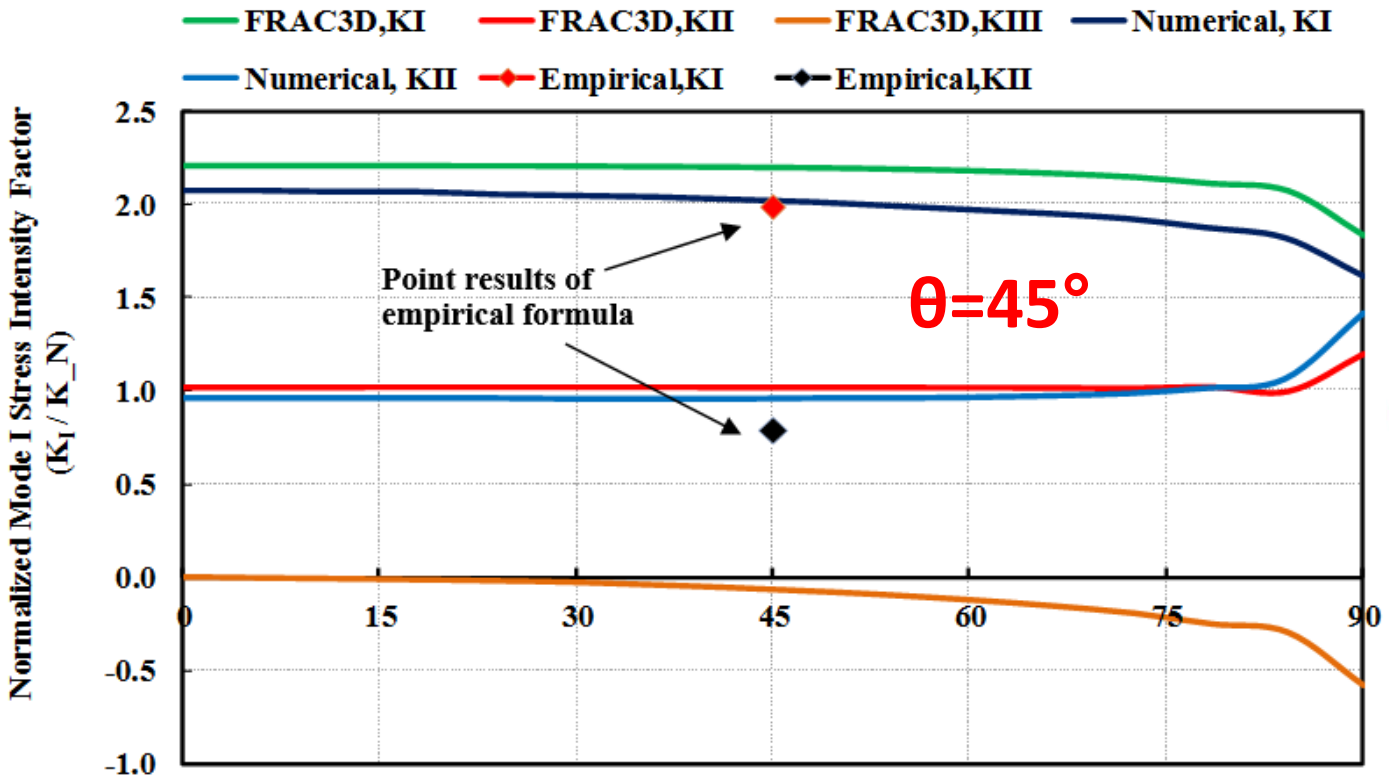
Meshing

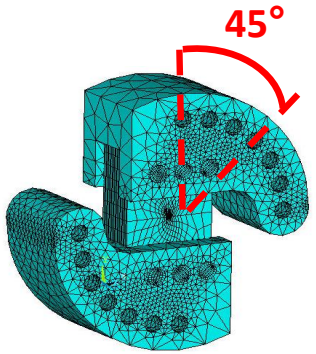


Modeling by ANSYS

Numerical Studies

Comparison and Validation of FRAC3D Results

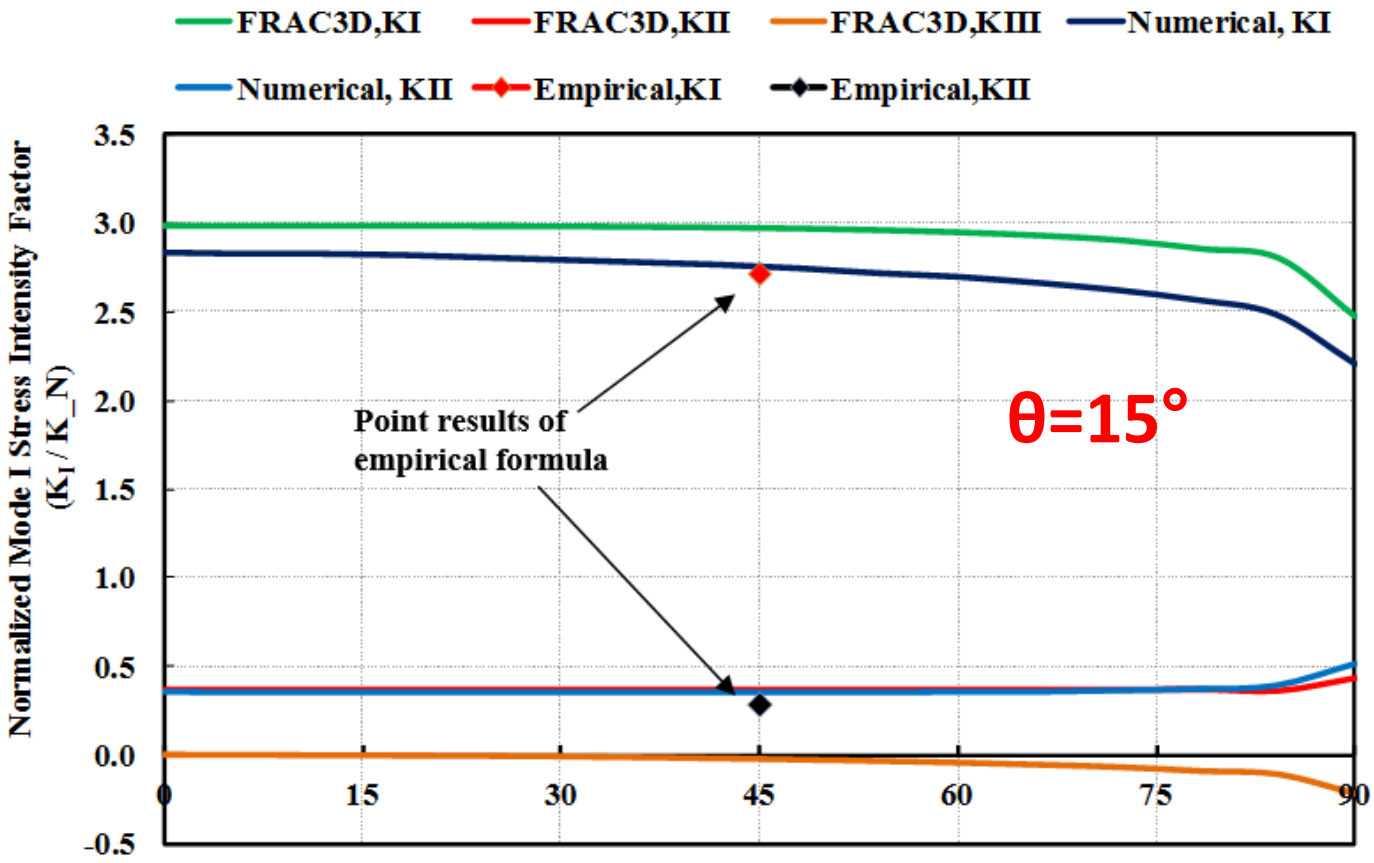


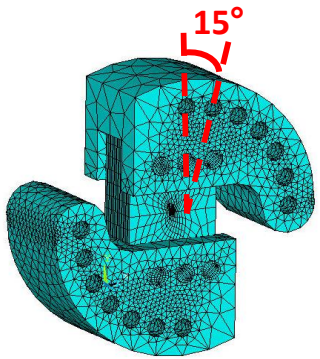


Variations of stress intensity factors along the crack front, comparisons of results from FRAC3D, numerical results and empirical results, **45 degree loading**

Numerical Studies

Comparison and Validation of FRAC3D Results



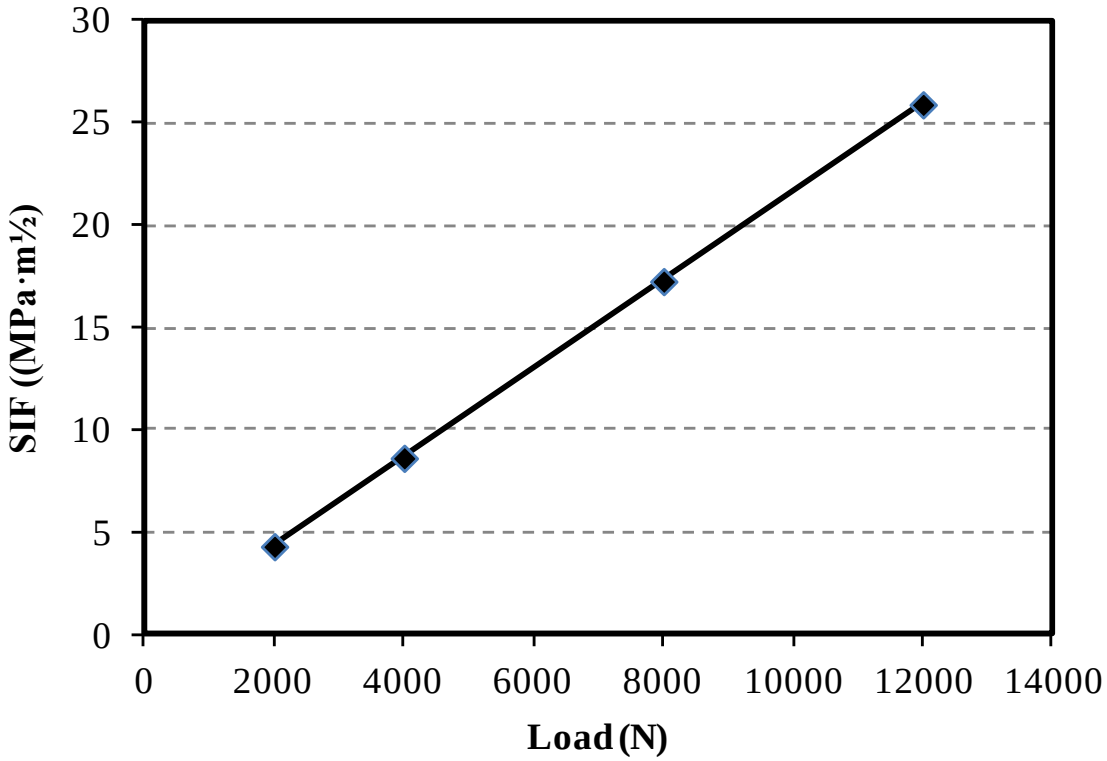


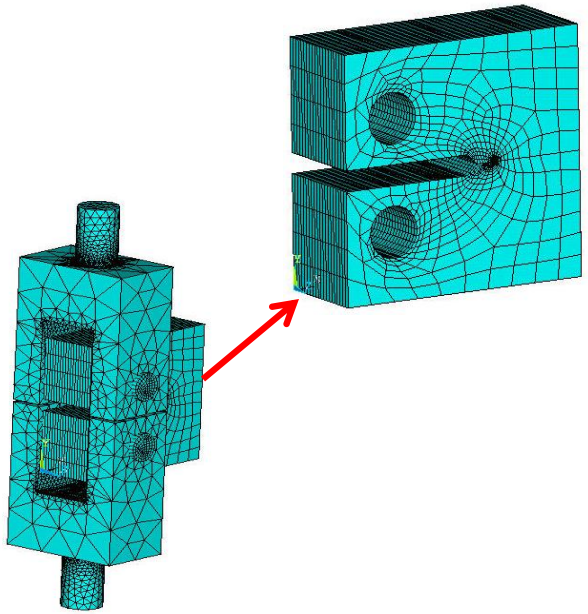
Variations of stress intensity factors along the crack front, comparisons of results from FRAC3D, numerical results and empirical results, **15 degree loading**

Numerical Studies

Load Linearity Test Analyses

A number of contact and fracture analyses are performed for different loads under mode-I loading by using ANSYS and FRAC3D to check the linearity between the applied tension loads on the clevises increase and the stress intensity factor.

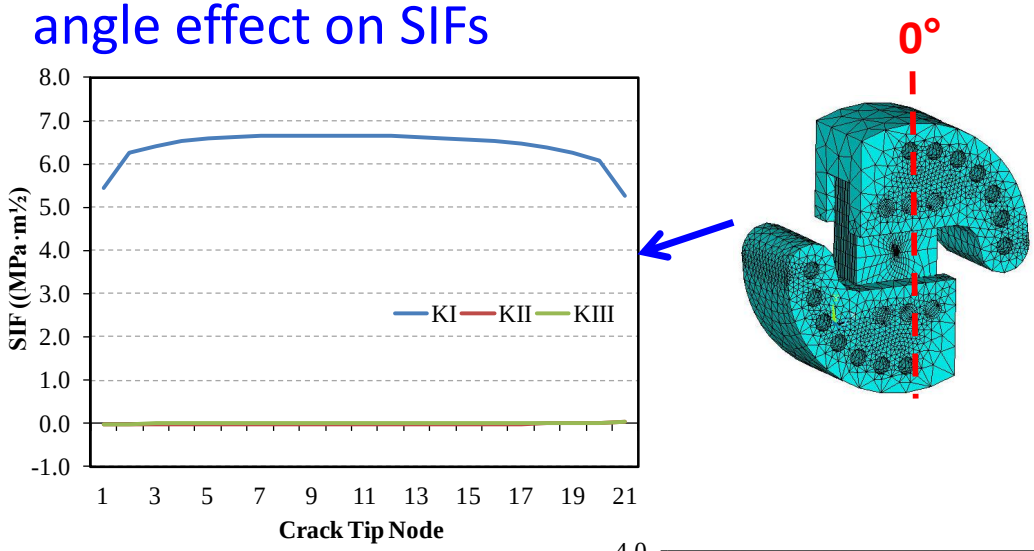


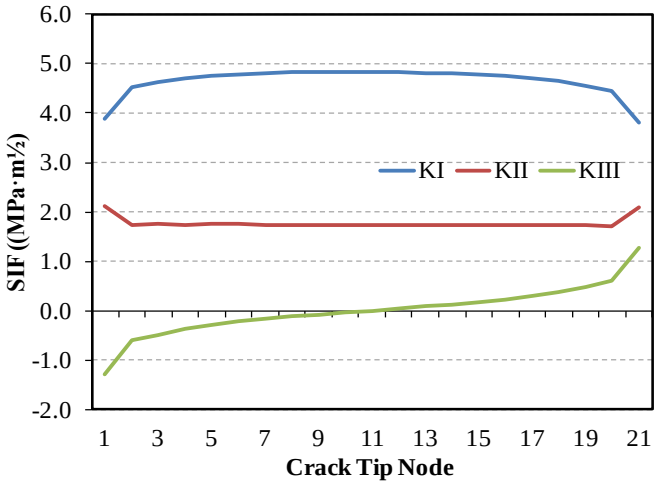


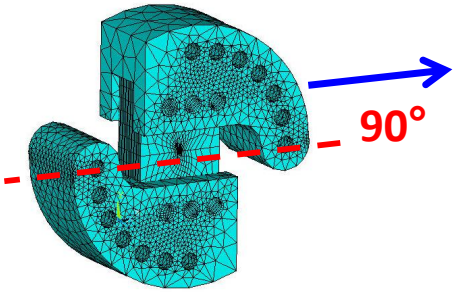
Numerical Studies

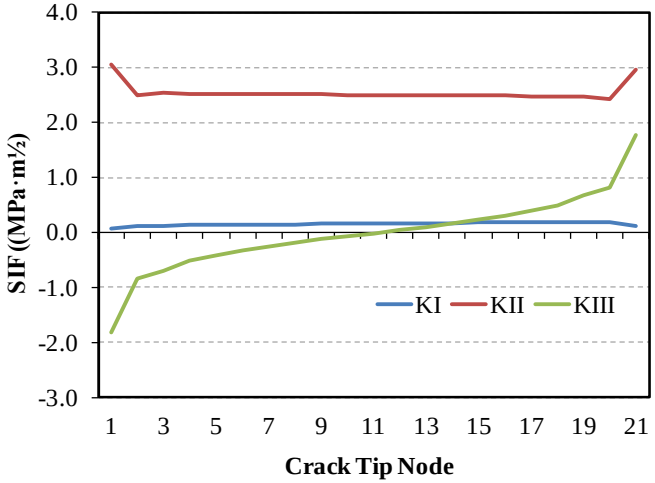
Loading and Boundary Condition Sensitivity Analyses

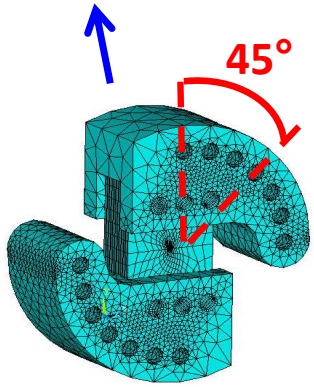
Three different analyses are performed using CTS specimen with different loading angles (0º, 45º, and 90º respectively) to see loading angle effect on SIFs







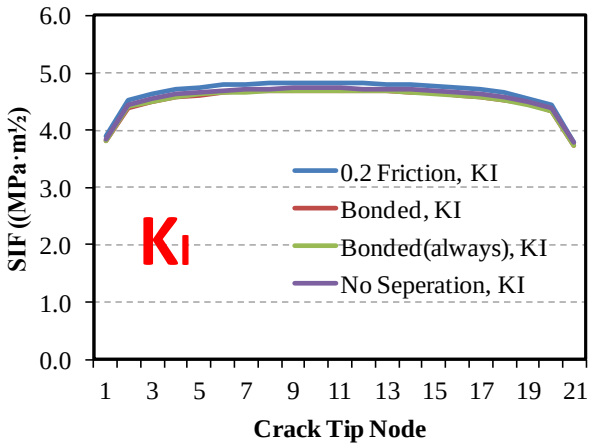


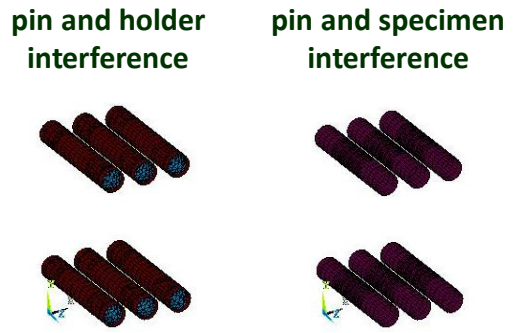


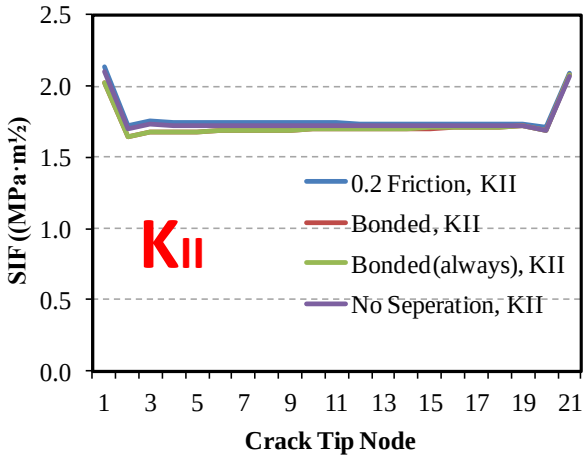
Numerical Studies

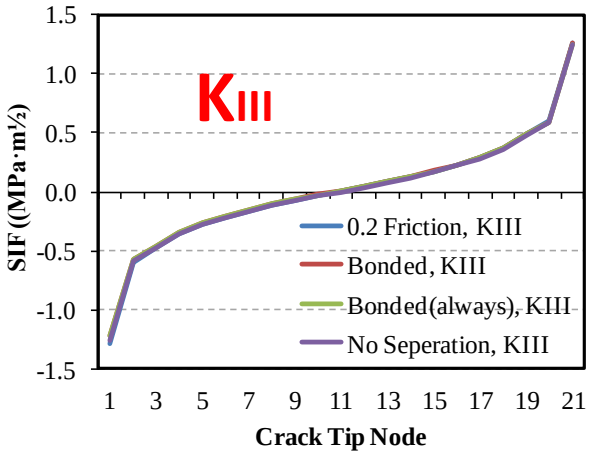
Contact Type and Boundary Condition Sensitivity Analyses

Some trial analyses are performed to investigate the contact type used in the analyses on the computed SIFs. Constant loading angle **(45 degree)** and load value **(10 kN)** are used in the analyses.





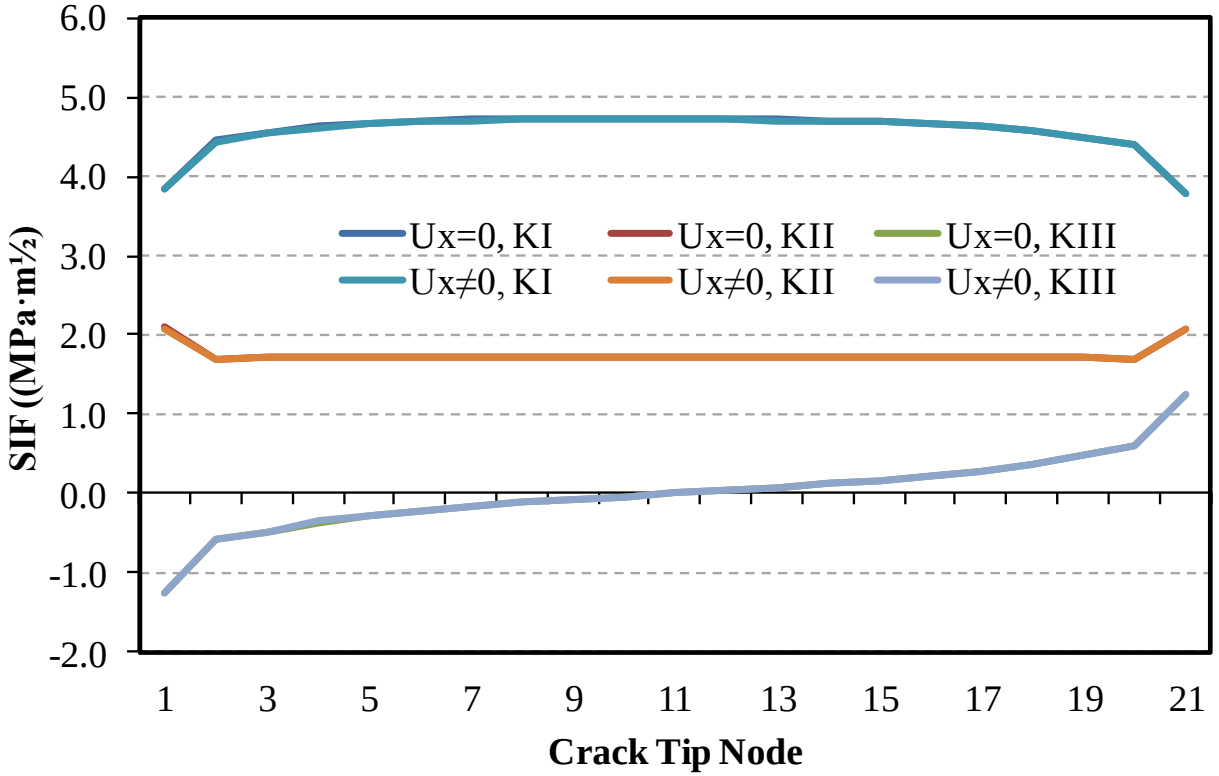


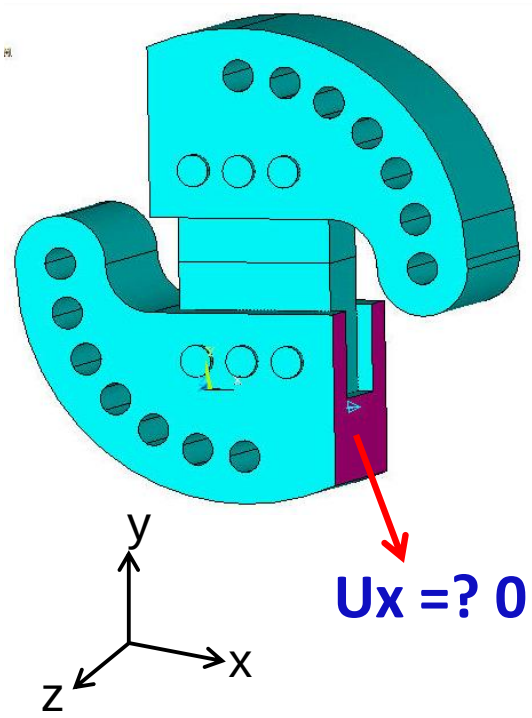


Numerical Studies

Contact Type and Boundary Condition Sensitivity Analyses

A few analysis are also performed to see the effect of the boundary conditions on SIFs. With and without applying zero displacement in X direction on the right side of the bottom clevis the difference between SIFs is compared in this analysis.

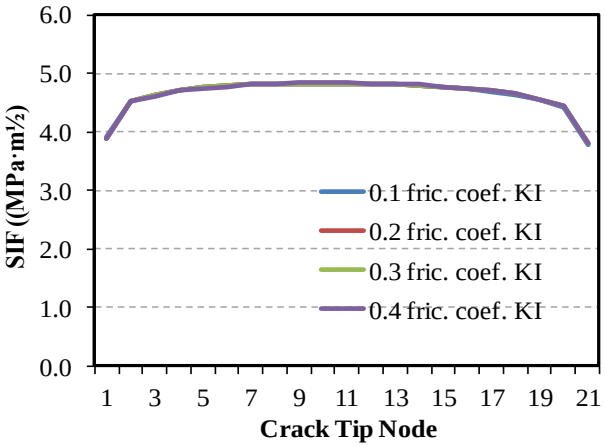


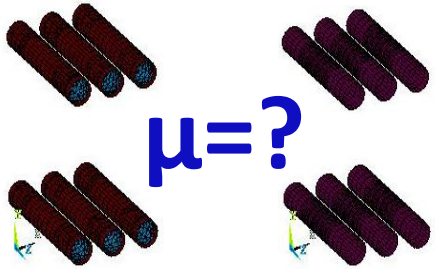


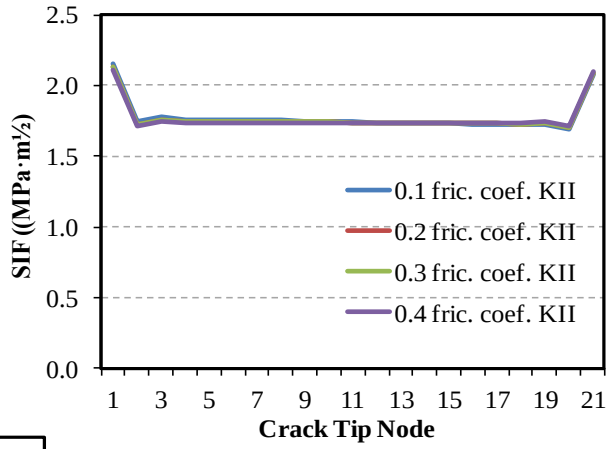
Numerical Studies

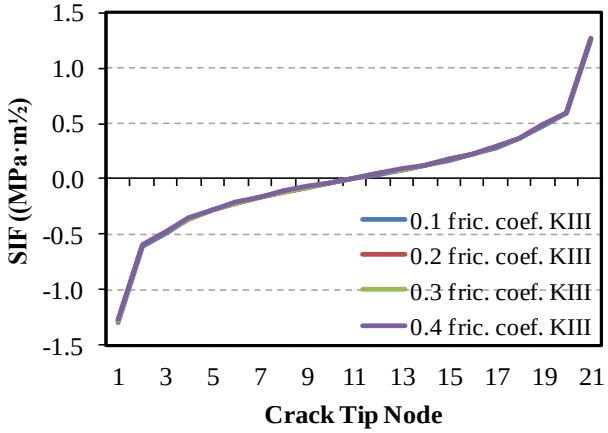
Friction Coefficient Sensitivity Analyses

For understanding friction coefficient effect between contact surfaces to analyses results, various analyses are performed with different friction coefficients









Summary and Conclusions

- Fracture analyses performed using FRAC3D showed good agreement with numerical and empirical results.

The presented results from the analyses are intended to be used for experimental studies in the near future.

- The results also show that under mode II loading, mode III stress intensity factor is also encountered, which varies and changes sign along the crack front.

- Linear relation between the SIFs and the the applied loads was presented.

- There is no difference between different cases of contacts; frictional (0.2 friction coefficient), no seperation, bonded and bonded (always) and there is no effect on SIFs by appliying zero displacement on the right side of the bottom clevis.

- The SIFs along the crack front are almost identical between the analyses with different friction coefficients.

Acknowledgements

✓*Authors are thankful to The Scientific and Technological Research Council of Turkey (TUBITAK) for the financial support during FCPAS Project.*