TECHNION – IIT
Department of Mechanical Engineering

Modeling and Testing of Ceramic Armor Tile Survivability to Fragment Attack

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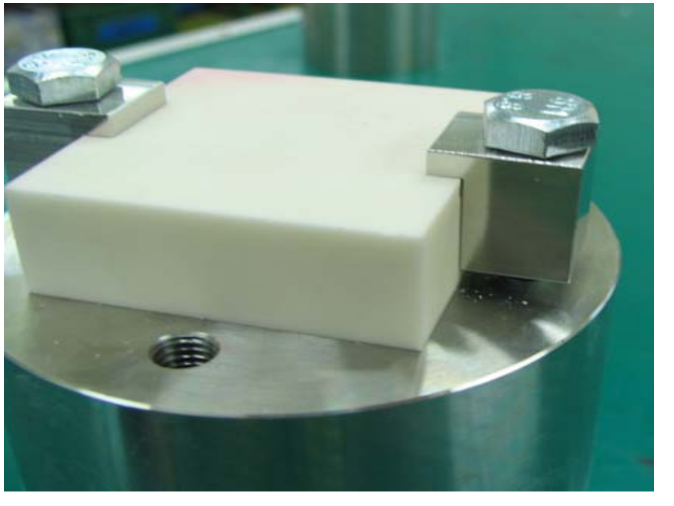
Outline

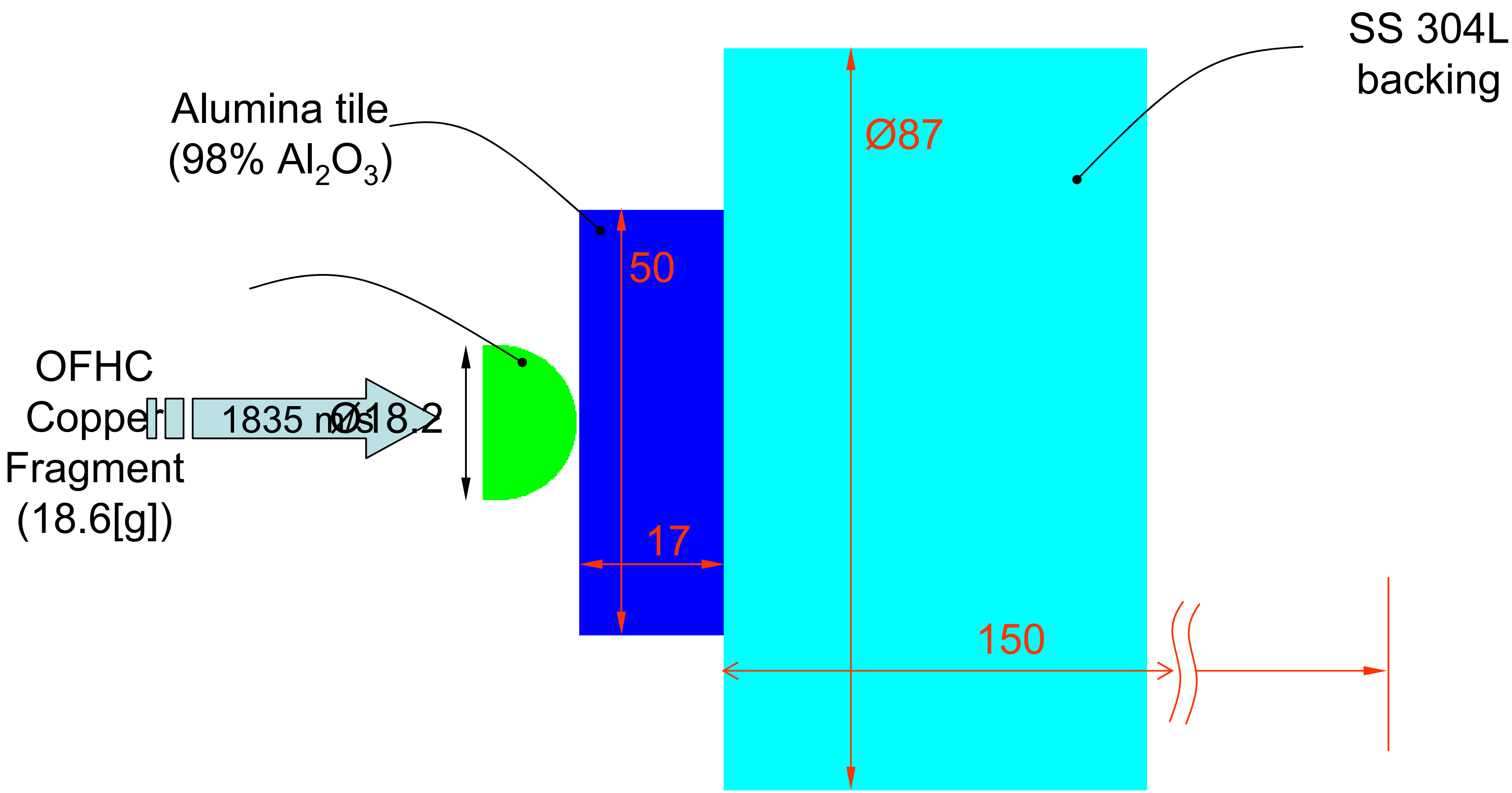
- Research objectives
- Experimental setup and results
- Simulation modeling
- Discussion
- Summary & Conclusions

Research Objectives

- Modeling a ceramic (Al_2o_3) armor as an IM shield against fragment attack.
- Comparing simulations data to the corresponding tests results.

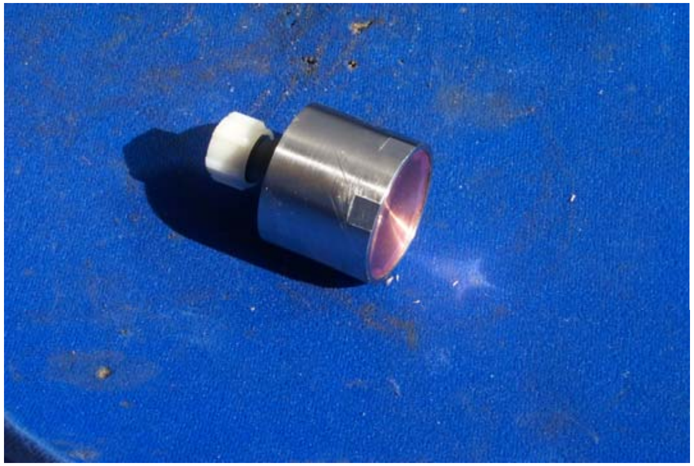


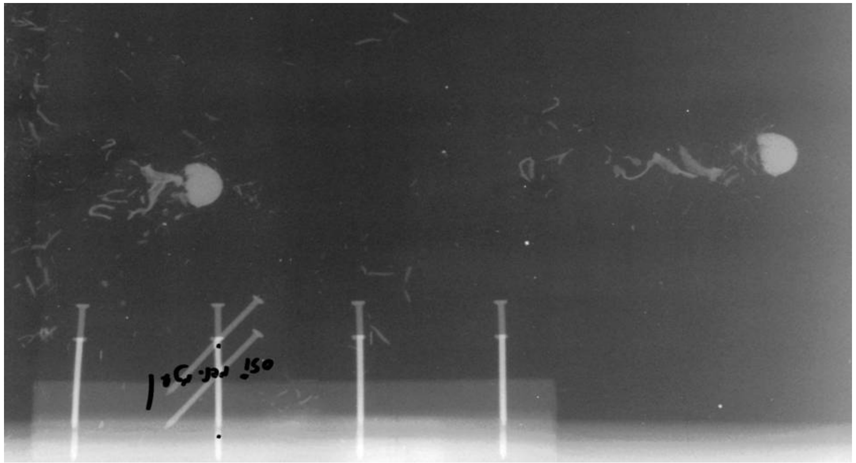
Test Setup


SS 304L backing
Alumina tile (98% Al_2O_3)
Ø87
50
OFHC Copper Fragment (18.6[g])
1835 m/s
Ø18.2
17
150

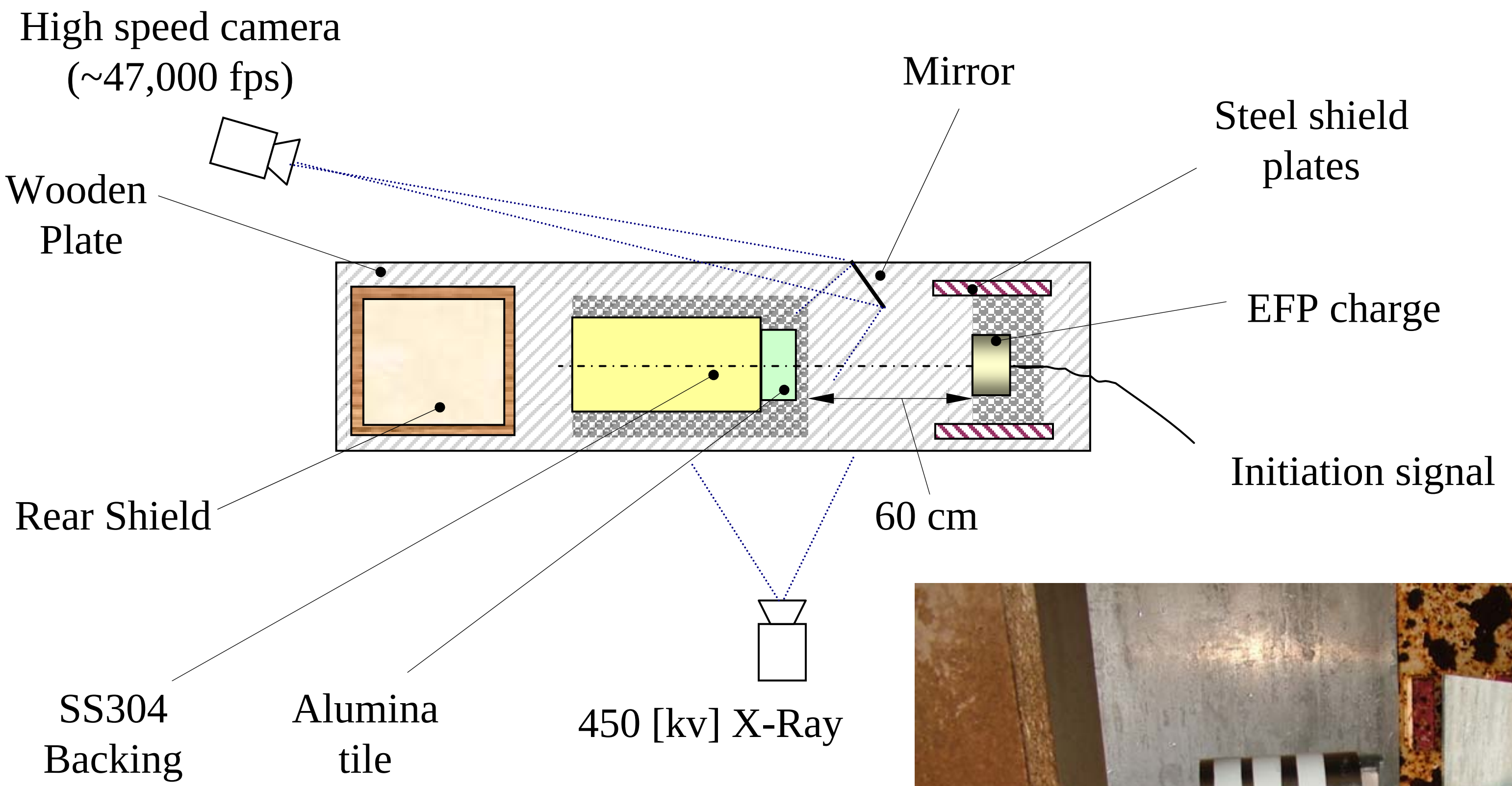
Fragment formation

- Fragment is formed from the initiation of an EFP charge.
- An EFP charge is an explosive charge, consists of a metal **casing** and a 18.6 [gr] copper **liner** (acc. to STANAG 4496).
- After the initiation, the copper liner transforms into a hemispheric shaped fragment.
- Fragment's K.E≈30KJ
- 0.5" AP K.E≈16KJ



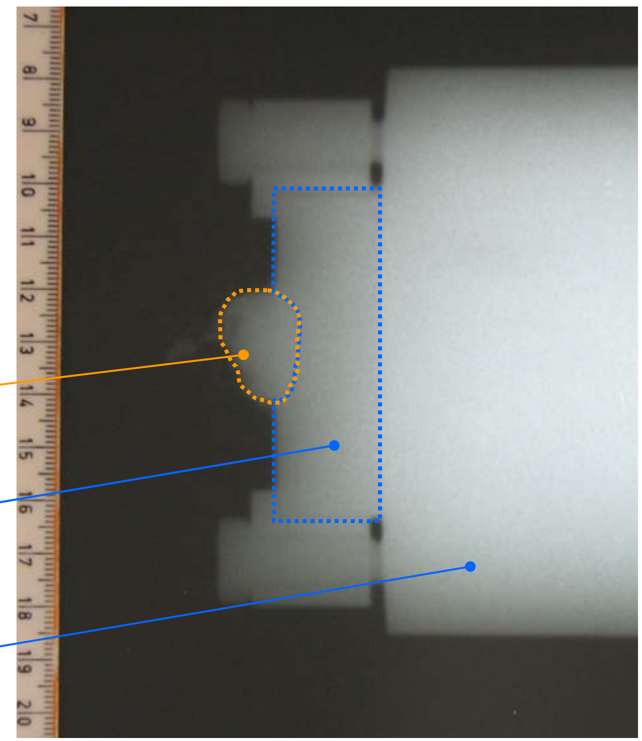


Detailed Experimental setup

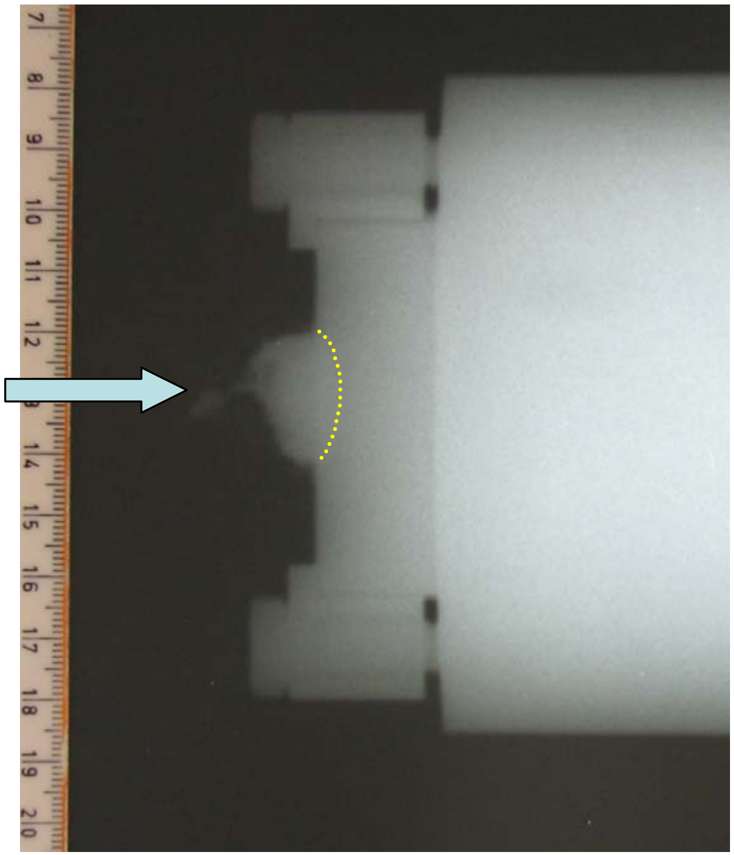


X-Ray

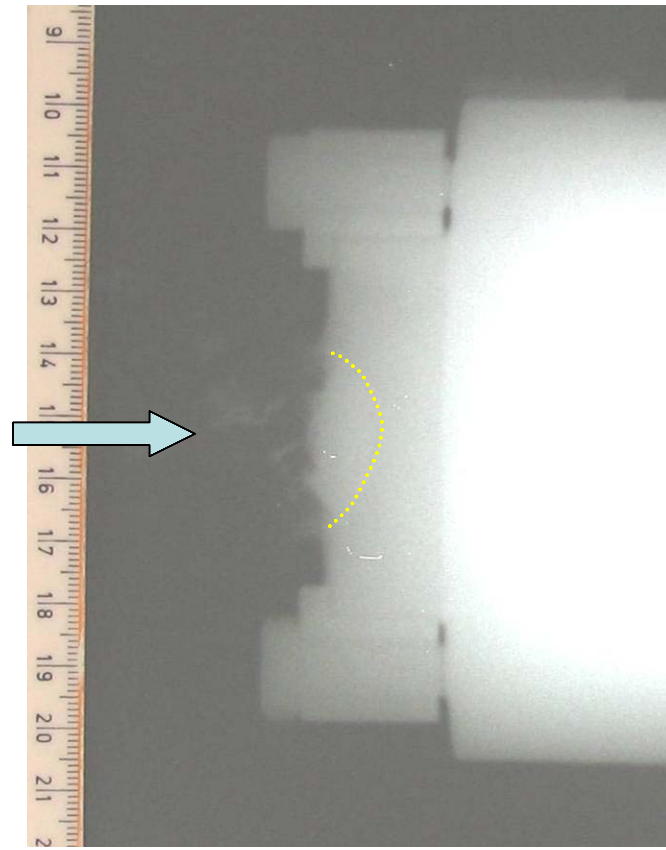
- A 450 [kv] Scandiflash X-Ray was used in order to examine the penetration process.
- 1st exp. flash time: 206 μs
- 2nd exp. flash time : 210 μs
- Parallax ratio = 0.83



Experiments Results – cont.



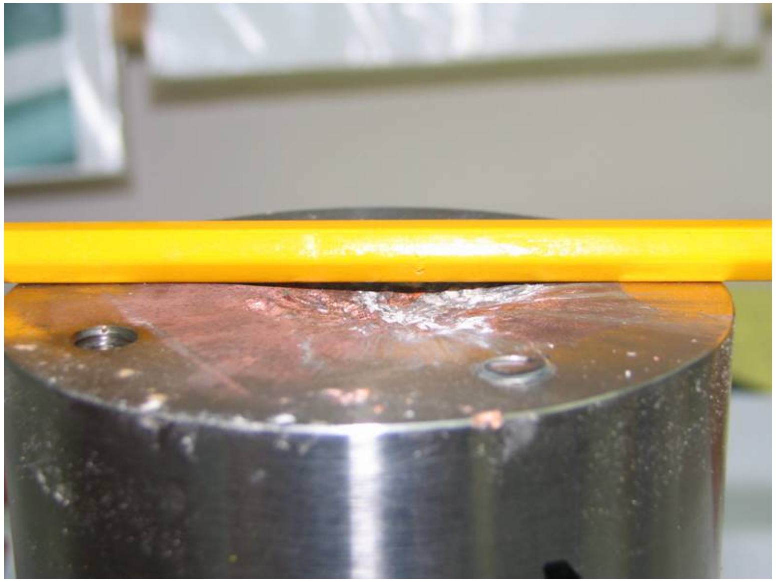
206μs

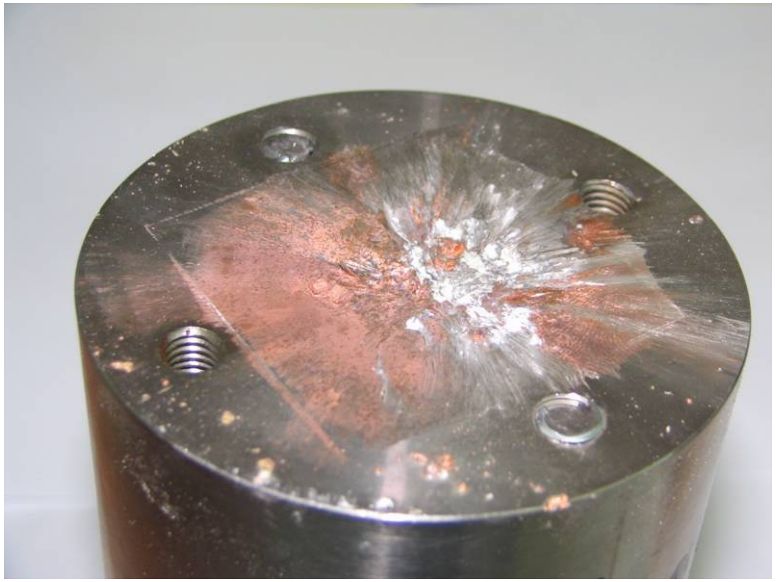


210μs

Experiments Results

- Two Experiments were conducted.
- 1st experiment D.O.P. = **3.4 [mm]**
- 2nd experiment D.O.P.= **3.7 [mm]**





Simulation Methods

- Autodyn v6.1 2D Lagrange solver has been used.
- Grid size convergence graph was done in order to optimize grid size and results convergence with computing resources.
- Parametric simulations were conducted, in order to evaluate different parameters and compare different constitutive models.
- Finally, fine grid size simulations were conducted on the chosen set of parameters.

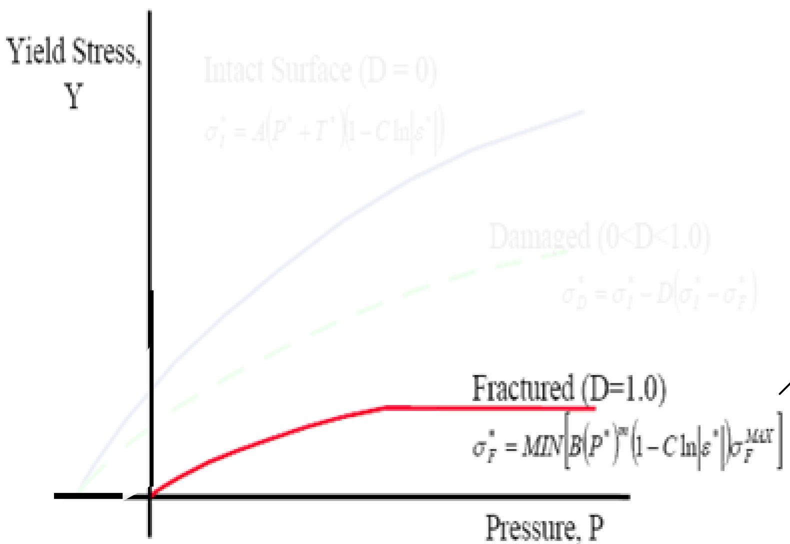
Simulation Modeling- Materials

Part	***Material***	***Equation of state***	***Strength Model***	***Failure Model***	***Source***
Ceramic Tile	Alumina (98%)	Polynomial	Johnson Holmquist	Johnson Holmquist	Westerling and Lundberg (1995)
Fragment	Copper	Linear	Johnson Cook	Johnson Cook	Johnson and Cook (1985)
Backing	SS304	Shock	Steinberg Guinan	-	Steinberg (1991)

Simulated fragment penetration- Half problem

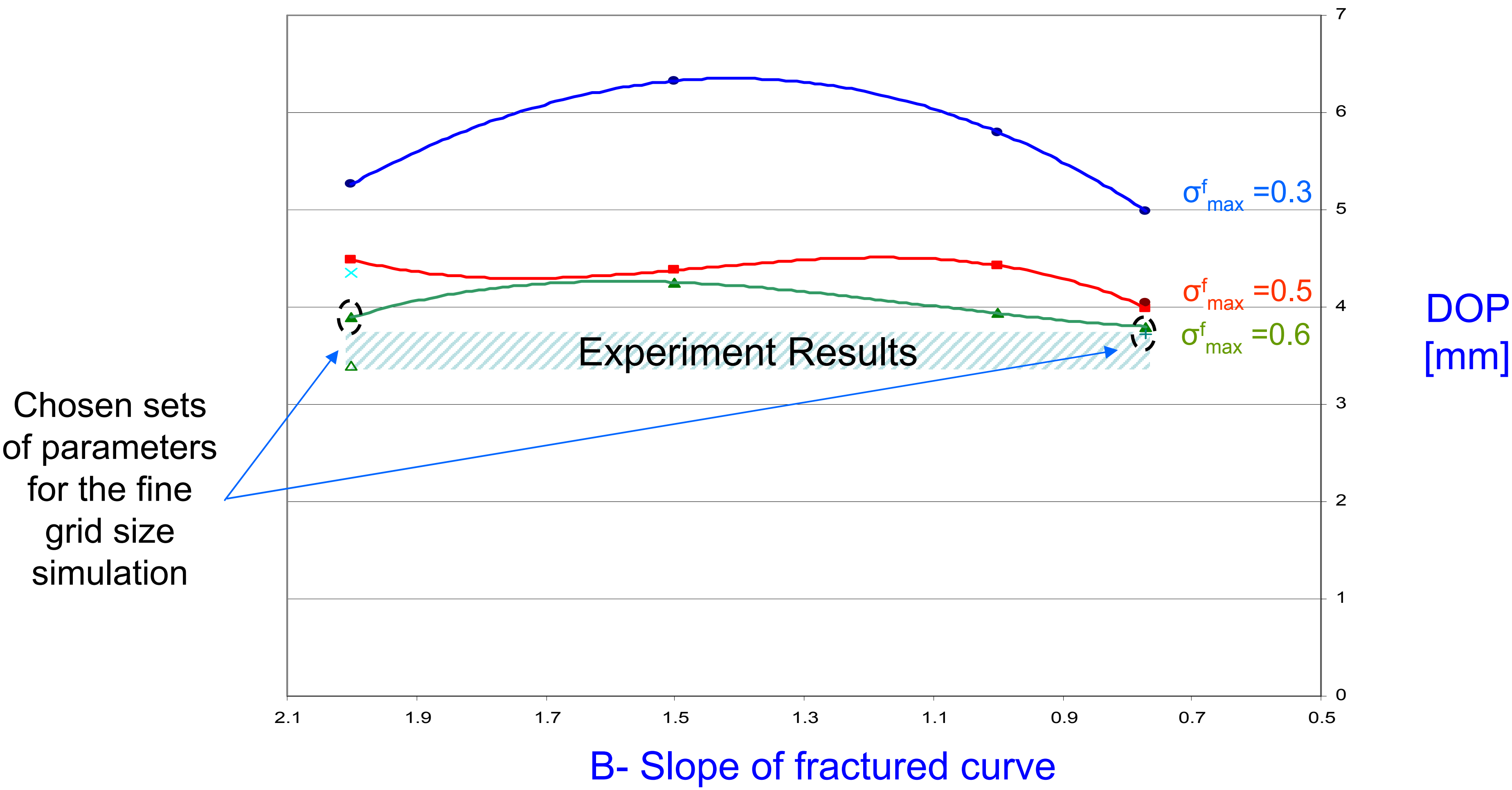
Alumina Modeling- J-H strength model

- Parameters that were investigated: **Fractured Curve**
  - B – slope of fractured curve
  - σ^{f}_{MAX}- dimensionless fractured strength upper limit$|_{@D=1}$



$$\sigma_F^* = MIN\left[B\left(P^*\right)^m\left(1 - C\ln\left|\varepsilon^*\right|\right)\sigma_F^{MAX}\right]$$

Parametric Simulations results



Literature Survey

Source	Alumina	Code	B	σ^f_{max}
Westerling et al. (1995)	99.7%	AUTODYN 2D (Lagrange)	0.77	0.5
Anderson et al. (1995)	99.5%	EPIC (SPH)	0.28	1
Lynch et al. (2006)	97.5%	Grim 2D (Euler)	0.86	0.5
Present work	98%	AUTODYN 2D (Lagrange)	0.77 Or 2	0.6

Discussion

- Original J-H model (JH2) gives good estimation of the D.O.P experimental results.
- For an exact match, a modification of the fractured material parameters is presented (σ^f_{max}, B).
- The 'σ^f_{max}' Parameter has a strong influence on the D.O.P results. Nevertheless, 'B' parameter doesn't show a directional trend.

Summary & Conclusions

- Two firing experiments were conducted in order to acquire D.O.P results.
- Experimental D.O.P results were compared to the corresponding simulations results.
- Simulations were carried out using Autodyn v6.1 2D Lagrange solver.
- A set of parameters were chosen (JH2 model) in order to match the experimental results.

Future work…

- Further experiments on the same armor:
    - 1600 [m/s] fragment
    - 2500 [m/s] fragment
    - Bullet Impact
- Weight optimization (backing) for the armor is needed for commercial use.

The End