

# Internal Ballistic Simulation, Jericho Pistol



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## About IWI

- Israeli Weapon Industries (IWI) a world leader in innovative small arms
- Designs, produces and sells small arms
- The IWI product range and accessories are deployed by the IDF and many other leading security organizations.
- Among our products: Tavor, Negev, X95, Galil, Jericho and the legendary UZI





## Our simulations

- Each weapon contains many mechanisms.
- A critical synchronization is necessary for functionality.
- Short time events with very high impacts.
- Multiphysics simulations capabilities using MBD, Radioss and Optistruct.
- An integral stage in the R&D and Engineering process.
- Saving time, money and resources.

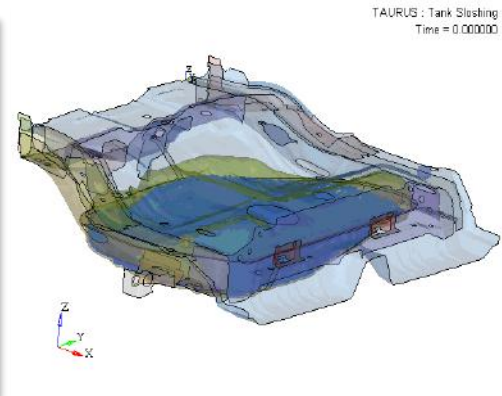
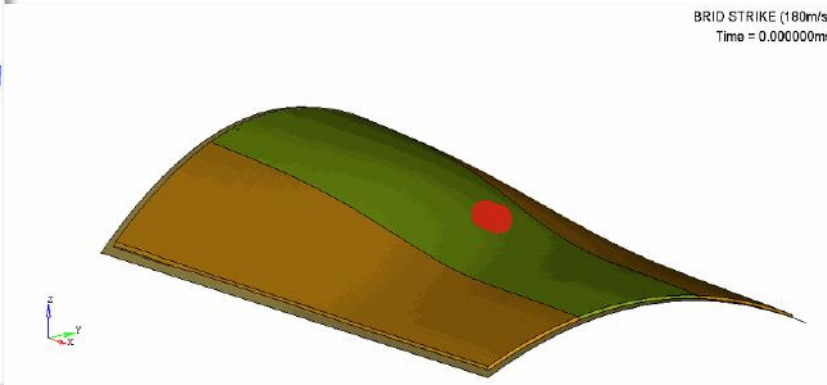
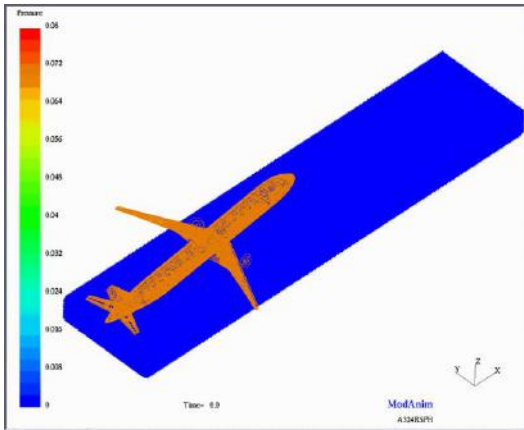


# RADIOSS – What does it solve?

## Fluid/Structure Interactions

- Sloshing & Slamming problems especially in shipbuilding industry
- Wave impacts on offshore structures
- Ditching of aero planes
- Bird strikes, water impacts, .....

SPH and ALE solutions

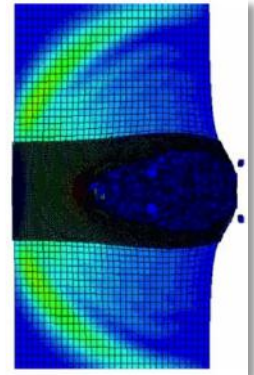
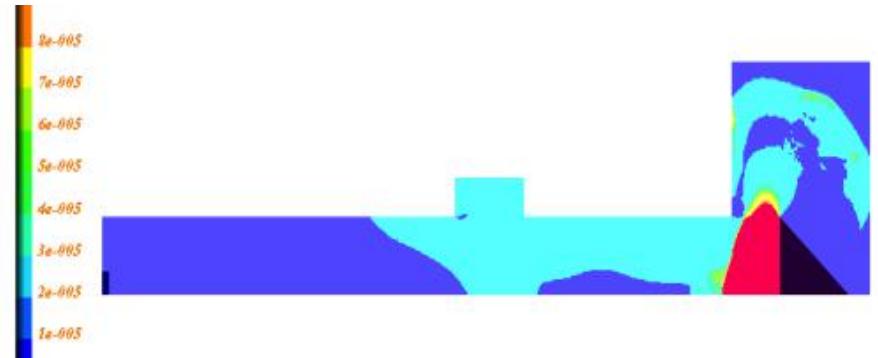
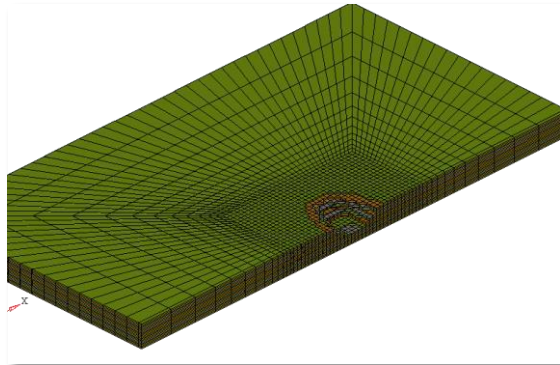
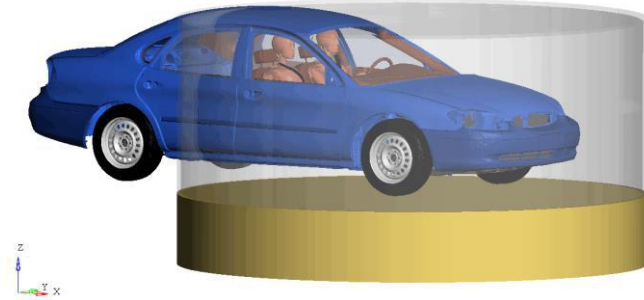


# RADIOSS – What does it solve?

TARUS on mine  
Time = 0.0000e+000 ms

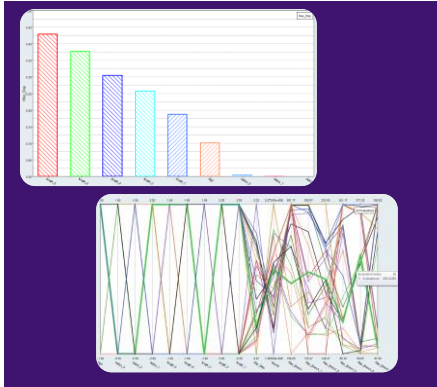
## Blast & Hydrodynamic Impact

- Explosion mechanism studies
- Blast effects on structures (effect of a mine on a vehicle, ..)
- Meteoritic impacts
- Military systems functioning (shape charges, ...)



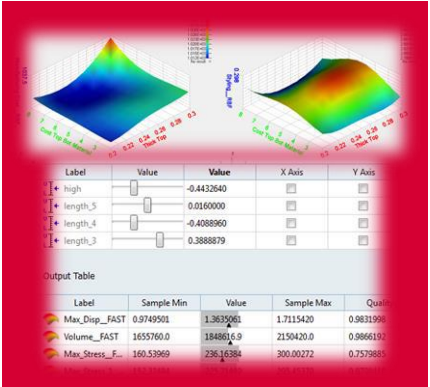
# WITH HYPERSTUDY YOU CAN

Investigate relationships



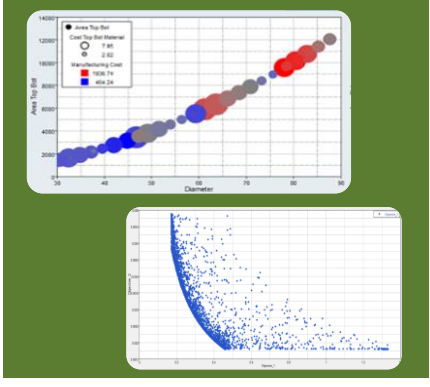
Design of Experiments

Make predictions



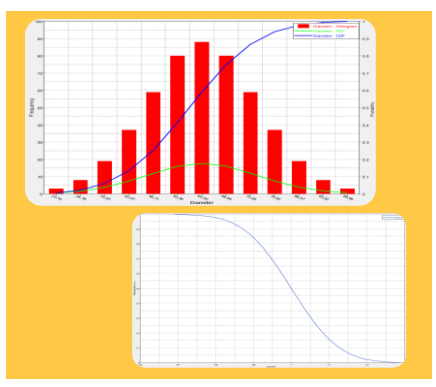
Fit

Identify best design



Optimization

Assess reliability



Stochastic





## Problem definition

- Performing a complete gun firing simulation.
- Determine gun powder properties.
- Create new workaround for complete Multiphysics simulations.
- Contact and general model behavior.
- Use real testing results to learn HyperStudy.
- When confident in results – future research of developed products using FSI method.

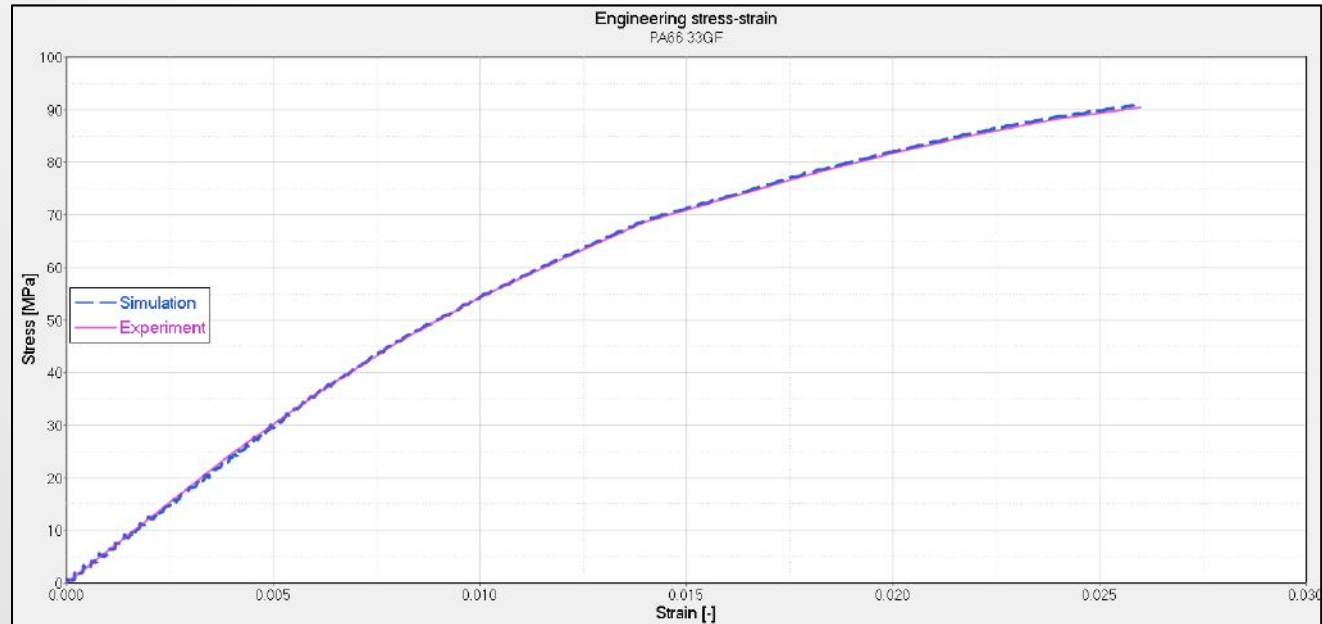


## Problem definition



## Mat. calibration

- All Elasto-plastic materials modeled with material LAW36.
- Total of 7 materials was used for the Simulation.
- All materials was simulated and compared to experiment.
- LAW36 Tensile failure model using  $\epsilon_t$ ,  $\epsilon_m$ ,  $\epsilon_f$ .
- Excellent in terms of stiffness.
- failure model still to be calibrated to reach proper necking in ductile materials.







Problem definition



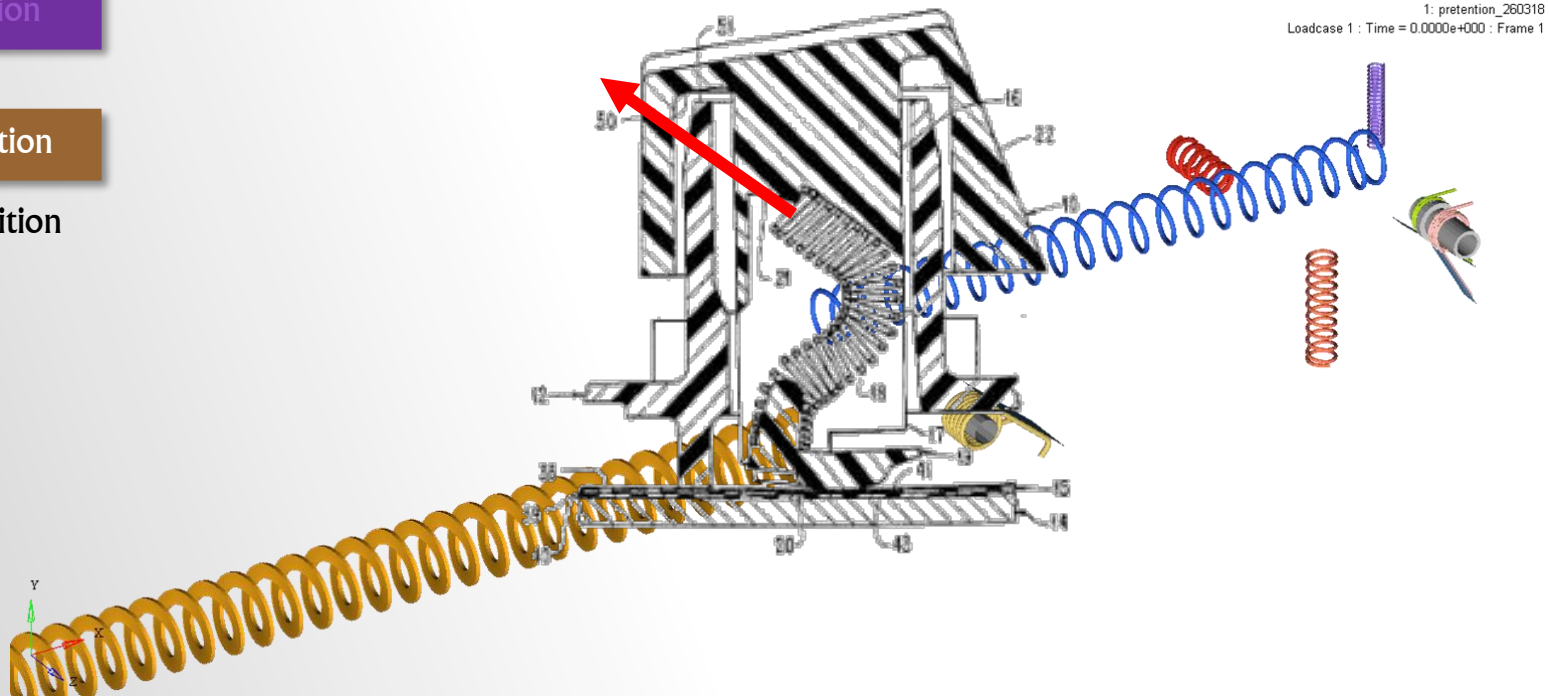
Mat. calibration



Spring calibration



Definition





Problem definition



Mat. calibration



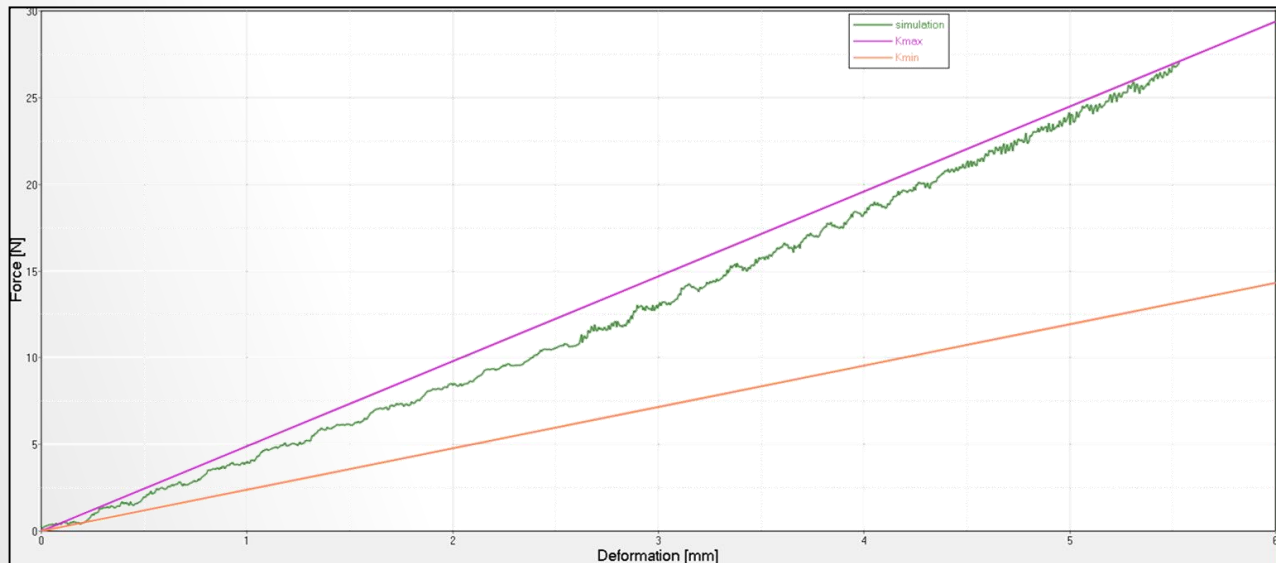
Spring calibration



Definition



Stiffness calibration





Problem definition



Mat. calibration



Spring calibration

Definition

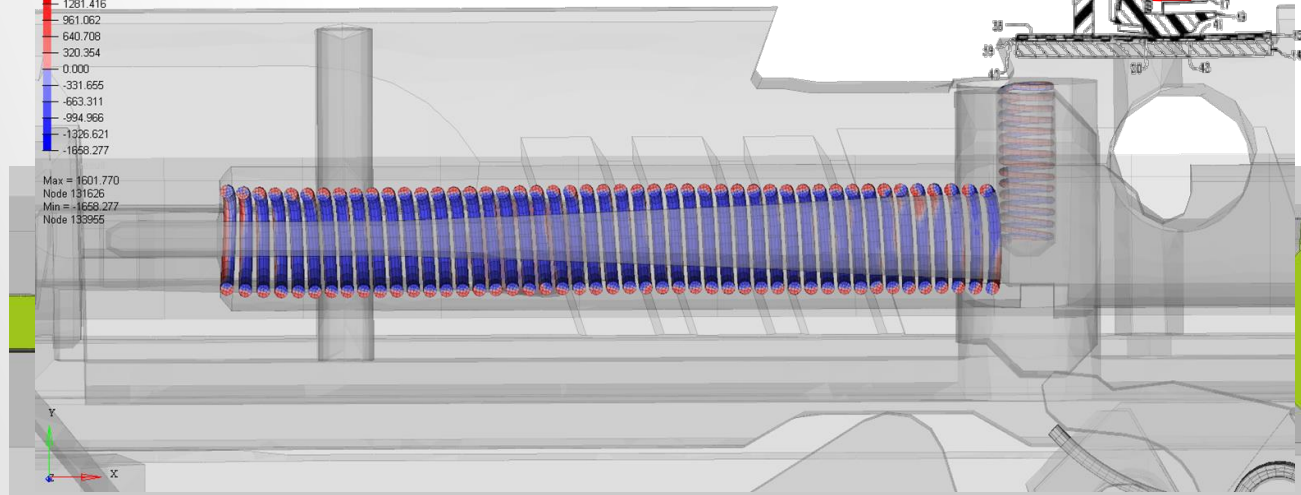
Stiffness calibration

Sta files

Contour Plot  
Stress(SignedVonMises)  
Analysis system  
Simple Average



Max = 1601.770  
Node 131626  
Min = -1650.277  
Node 133955



Problem definition

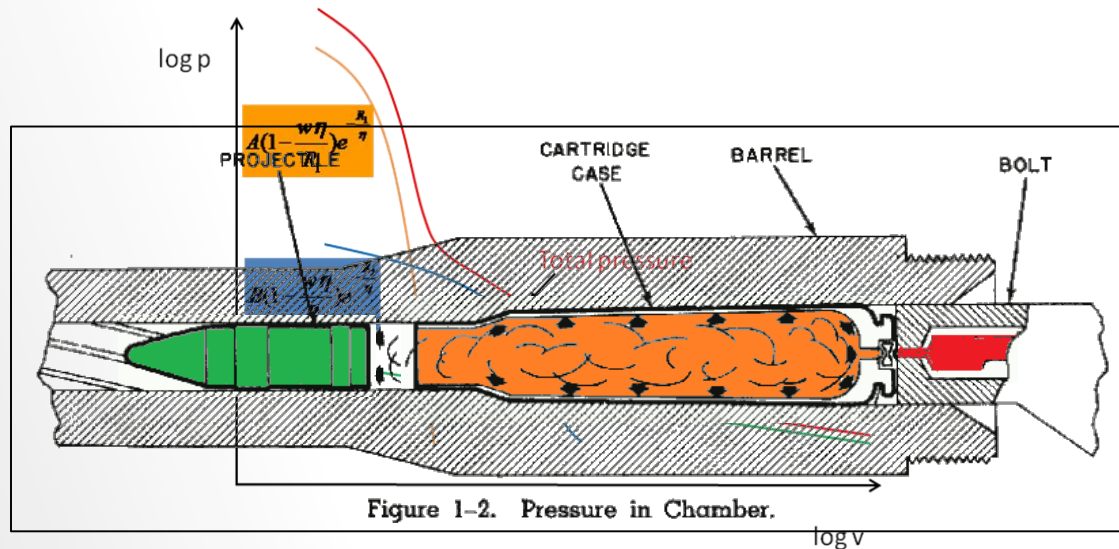
Mat. calibration

Spring calibration

JWL calibration

Equation of state

$$P = A \left( 1 - \frac{\omega}{R_1 V} \right) e^{-R_1 V} + B \left( 1 - \frac{\omega}{R_2 V} \right) e^{-R_2 V} + \frac{\omega E}{V}$$



Problem definition

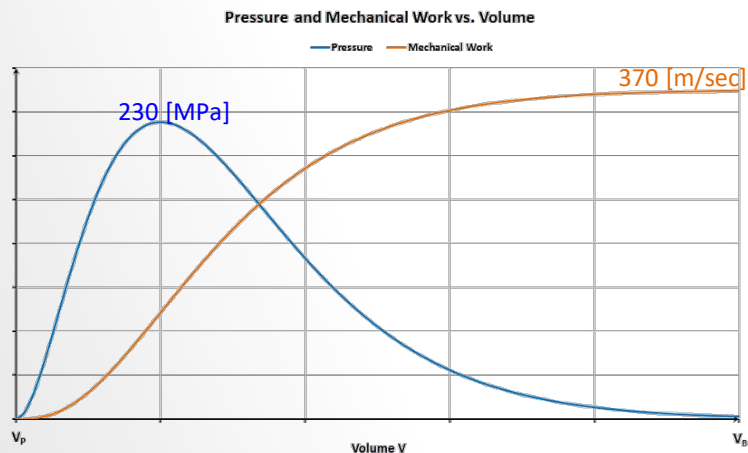
Mat. calibration

Spring calibration

JWL calibration

Equation of state

$$P = A \left( 1 - \frac{\omega}{R_1 V} \right) e^{-R_1 V} + B \left( 1 - \frac{\omega}{R_2 V} \right) e^{-R_2 V} + \frac{\omega E}{V}$$



A	A parameter of equation of state (Real)
B	B parameter of equation of state (Real)
$R_1$	$R_1$ parameter of equation of state (Real)
$R_2$	$R_2$ parameter of equation of state (Real)
$\omega$	$\omega$ parameter of equation of state (Real)
D	Detonation velocity (Real)
$P_{C1}$	Chapman Jouguet pressure (Real)
$E_0$	Detonation energy per unit volume (Real)

**Problem definition**

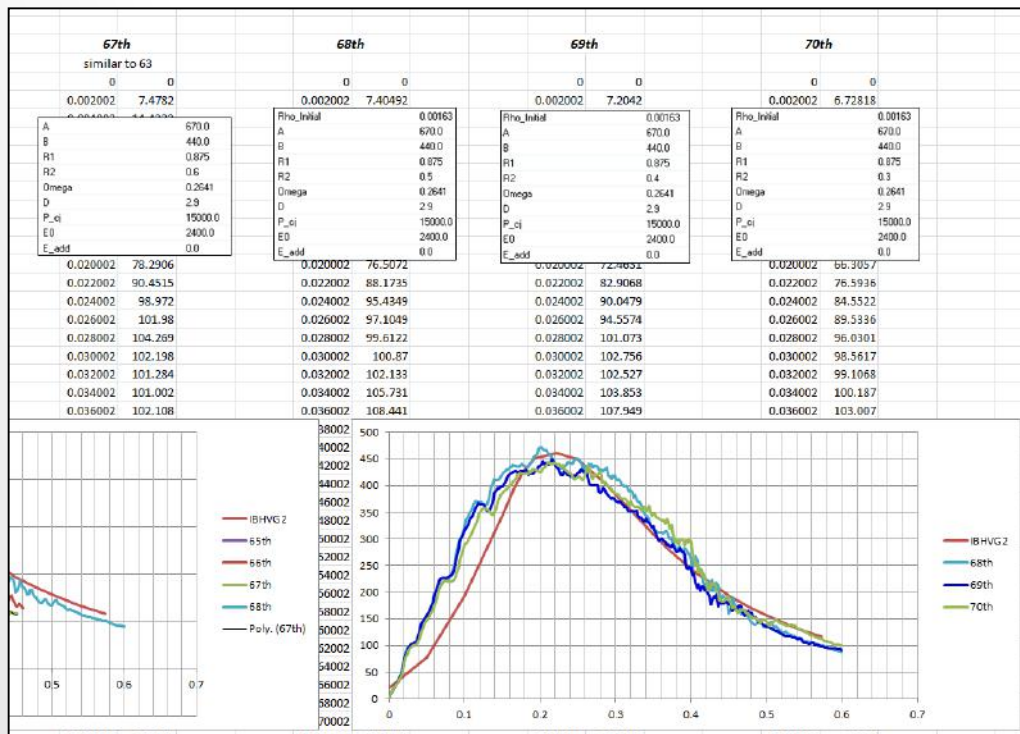
**Mat. calibration**

**Spring calibration**

**JWL calibration**

**Equation of state**

$$P = A \left( 1 - \frac{\omega}{R_1 V} \right) e^{-R_1 V} + B \left( 1 - \frac{\omega}{R_2 V} \right) e^{-R_2 V} + \frac{\omega E}{V}$$



Problem definition

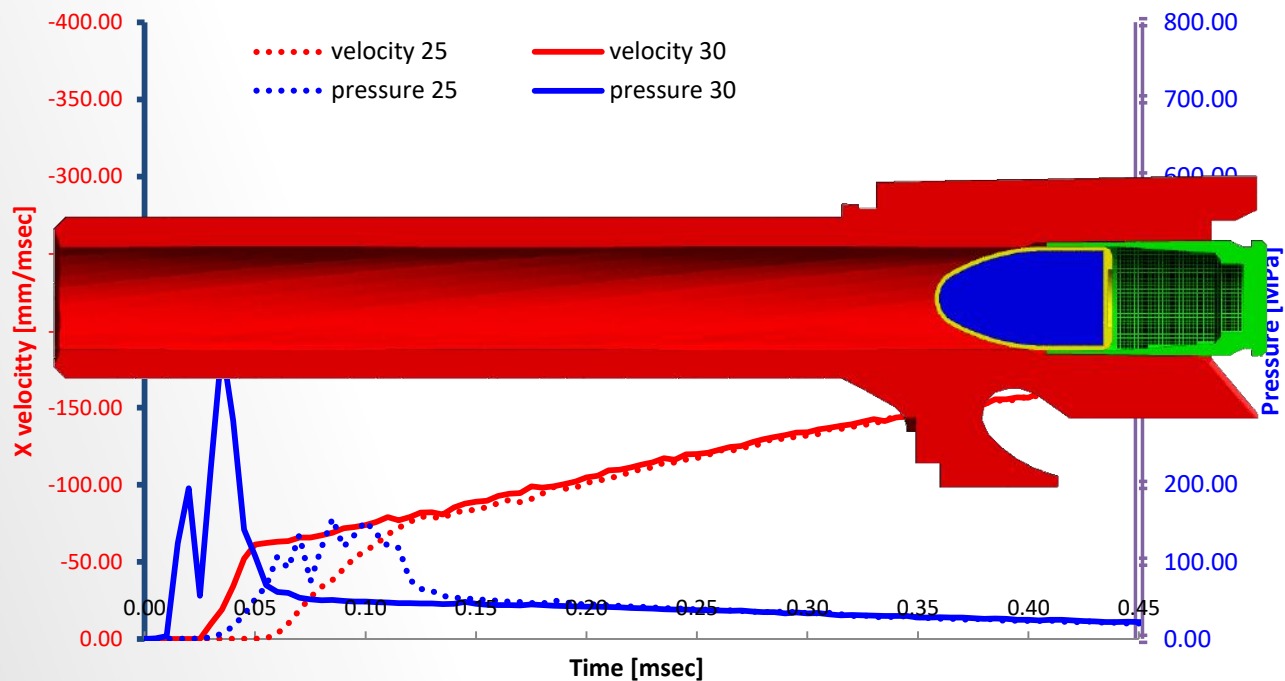
Mat. calibration


Spring calibration


JWL calibration


Equation of state


## Simulation results



 Problem definition

 Mat. calibration

 Spring calibration

 JWL calibration

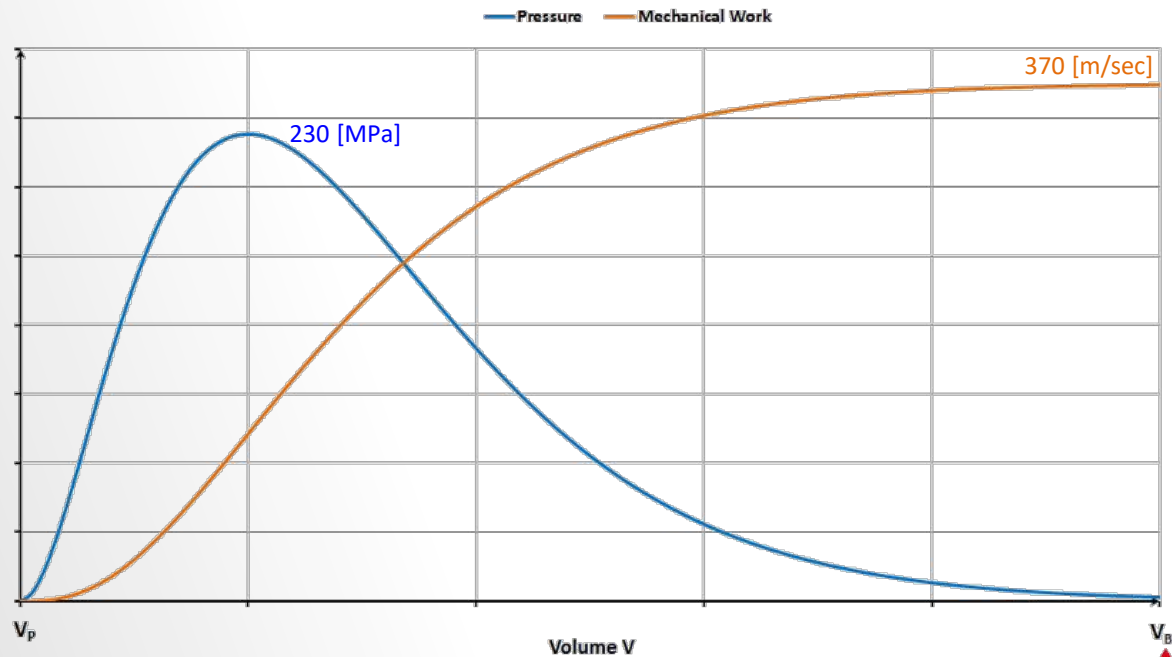
Equation of state

HyperStudy


### Hyperstudy-


- Objective : velocity = -370 [m/sec]
- Constraint : gun powder maximum pressure of 250 [MPa].


Pressure and Mechanical Work vs. Volume






 Problem definition

 Mat. calibration

 Spring calibration

 JWL calibration

Equation of state

HyperStudy


### Hyperstudy-


- Objective : velocity =-370 [m/sec]
- Constraint : gun powder maximum pressure of 250 [MPa].


### Self iteration-


- Velocity =-280 [m/sec]
- Gun powder maximum pressure of 619 [MPa].

	$\sigma_{E+}$ A	$\sigma_{E+}$ B	$\sigma_{E+}$ R1	$\sigma_{E+}$ R2	$\sigma_{E+}$ w	$\sigma_{E+}$ E0	Response 1	Response 2
1	190.00000	250.00000	0.0900000	0.5000000	0.2000000	1680.0000	-277.76213	209.32007
2	221.35000	250.00000	0.0900000	0.5000000	0.2000000	1680.0000	-225.14655	194.65614
3	190.00000	275.00000	0.0900000	0.5000000	0.2000000	1680.0000	-282.85111	222.09027
4	190.00000	250.00000	0.1048500	0.5000000	0.2000000	1680.0000	-357.55978	272.97784
5	190.00000	250.00000	0.0900000	0.5825000	0.2000000	1680.0000	-293.64287	209.22499
6	190.00000	250.00000	0.0900000	0.5000000	0.2330000	1680.0000	-253.34409	197.70091
7	190.00000	250.00000	0.0900000	0.5000000	0.2000000	1957.2000	-365.70699	267.65228
8	176.02367	244.40991	0.0961533	0.5750000	0.1700000	1680.6844	-363.73111	255.86688
9	175.36000	243.14688	0.0968790	0.6694223	0.1920813	1680.9086	-381.13316	254.35487
10	190.76226	249.47385	0.0976374	0.6719971	0.1821219	1680.0267	-353.03839	251.23351
11	190.77017	249.12966	0.0968378	0.7505533	0.1774050	1680.0299	-355.51841	237.20837
12	190.80868	248.86379	0.0997516	0.7885713	0.1829999	1680.0321	-376.03282	255.53828
13	190.46060	248.05991	0.0983560	0.9500000	0.1688477	1680.1272	-380.52506	232.20427
14	190.52686	248.06477	0.0972028	0.8992631	0.1708913	1680.1181	-372.68421	235.45137
15	190.52222	247.95057	0.0965616	0.9046006	0.1696134	1680.1243	-373.73868	236.77994
16	190.53182	248.02716	0.0963152	0.9017760	0.1699531	1680.1191	-366.95678	236.13675

 Problem definition

 Mat. calibration

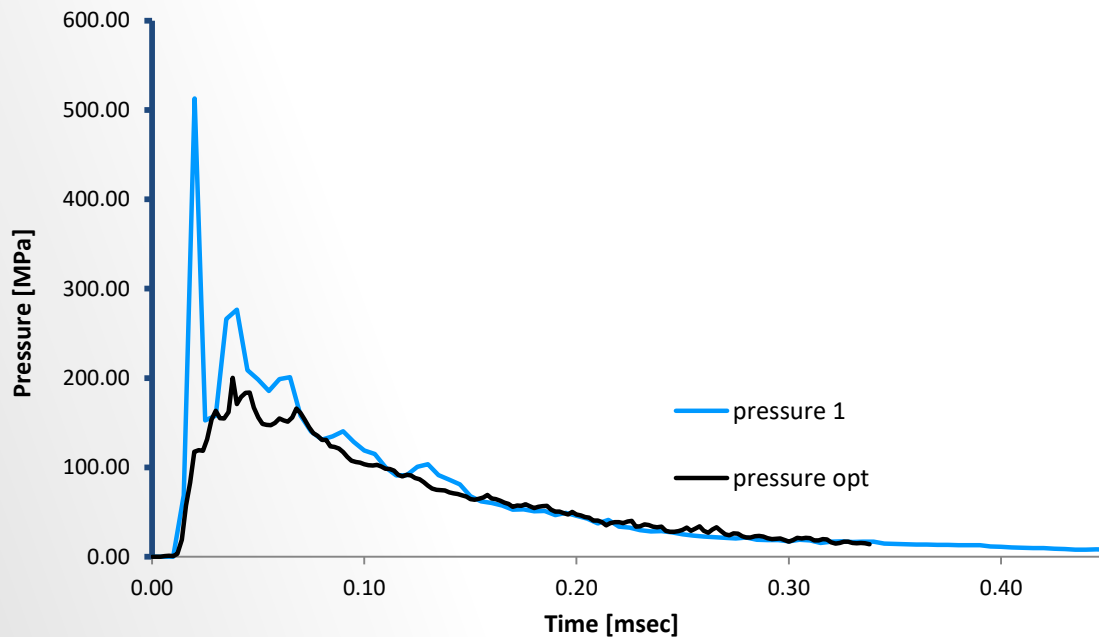
 Spring calibration


 JWL calibration


Equation of state


HyperStudy


Final result



 Problem definition

 Mat. calibration

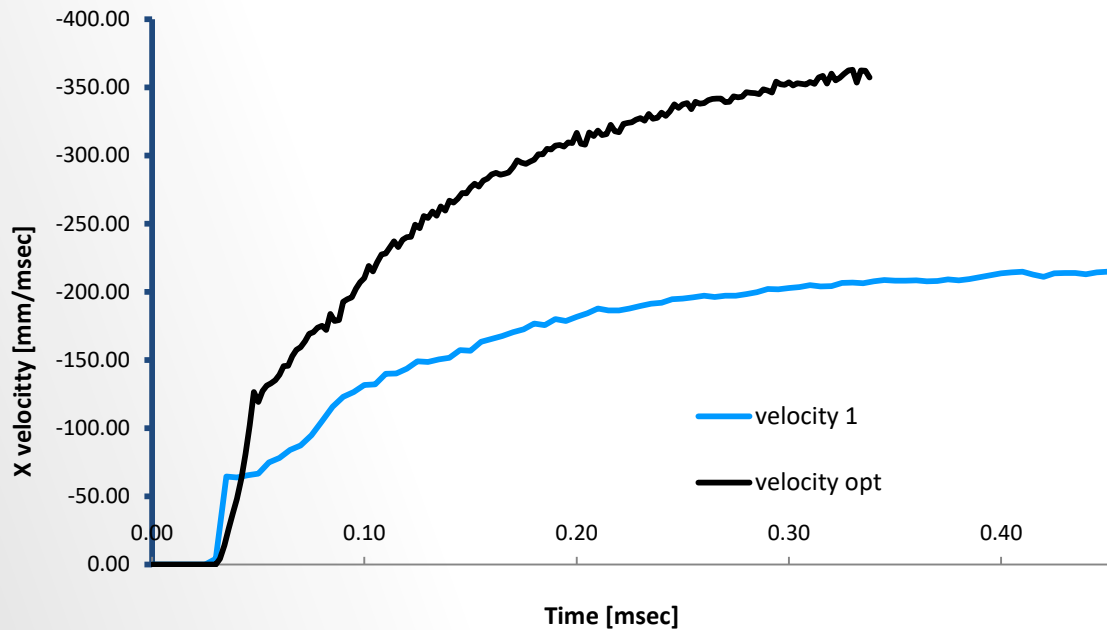
 Spring calibration

 JWL calibration

Equation of state

HyperStudy

Final result





Problem definition



Mat. calibration



Spring calibration



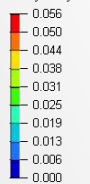
JWL calibration

Equation of state

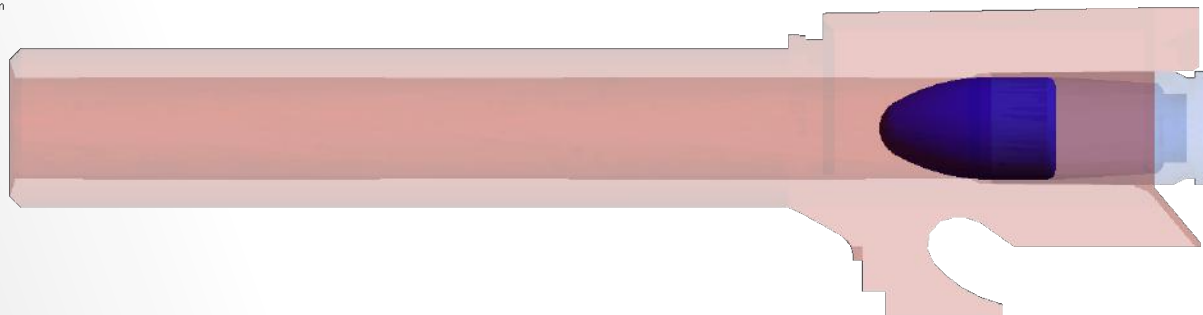
HyperStudy

Final result

Contour Plot  
Strain(vonMises)  
Analysis system

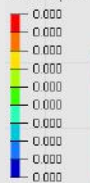


Max = 0.000  
SOLID 707630  
Min = 0.000  
SOLID 707630



1: SPH\_Bullet\_Detonation\_090418  
Loadcase 1 : Time = 0.0000e+000 : Frame 1

Contour Plot  
Pressure(Scalar value)



Max = 0.000  
SPHC EL 306557  
Min = 0.000  
SPHC EL 306557



1: SPH\_Bullet\_Detonation\_090418  
Loadcase 1 : Time = 0.0000e+000 : Frame 1



Problem definition



Mat. calibration



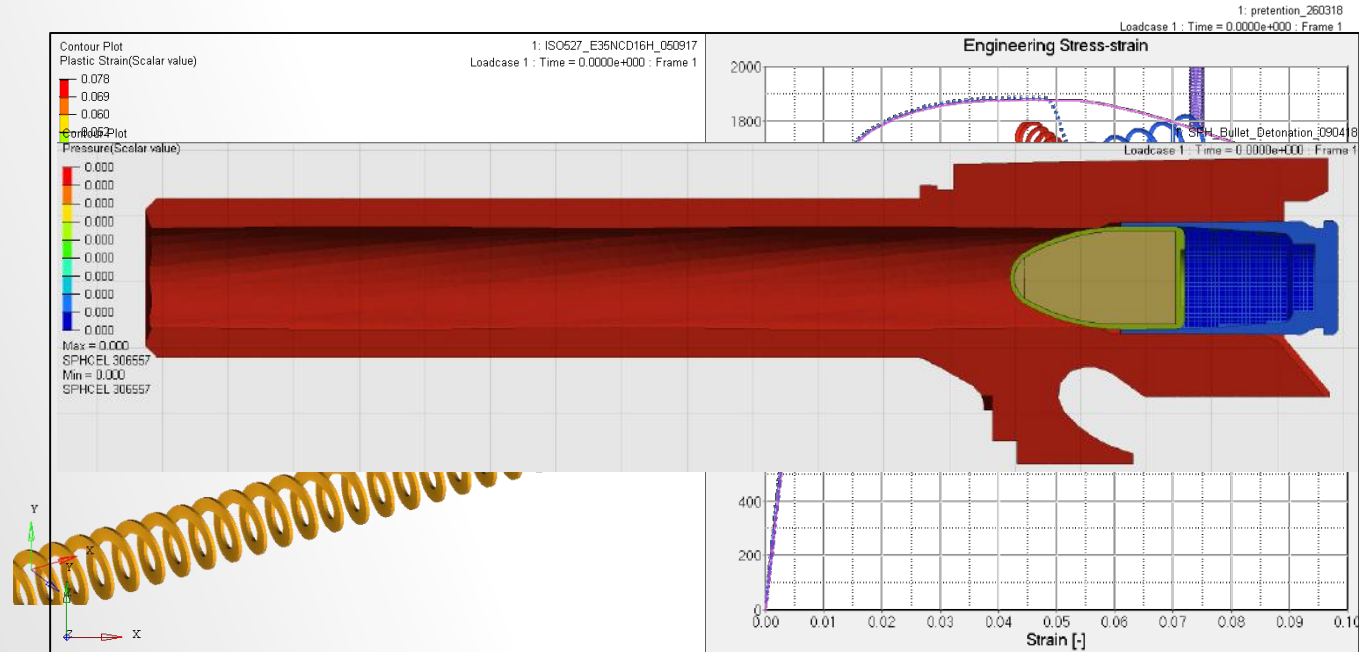
Spring calibration





JWL calibration





Running the job



 Problem definition

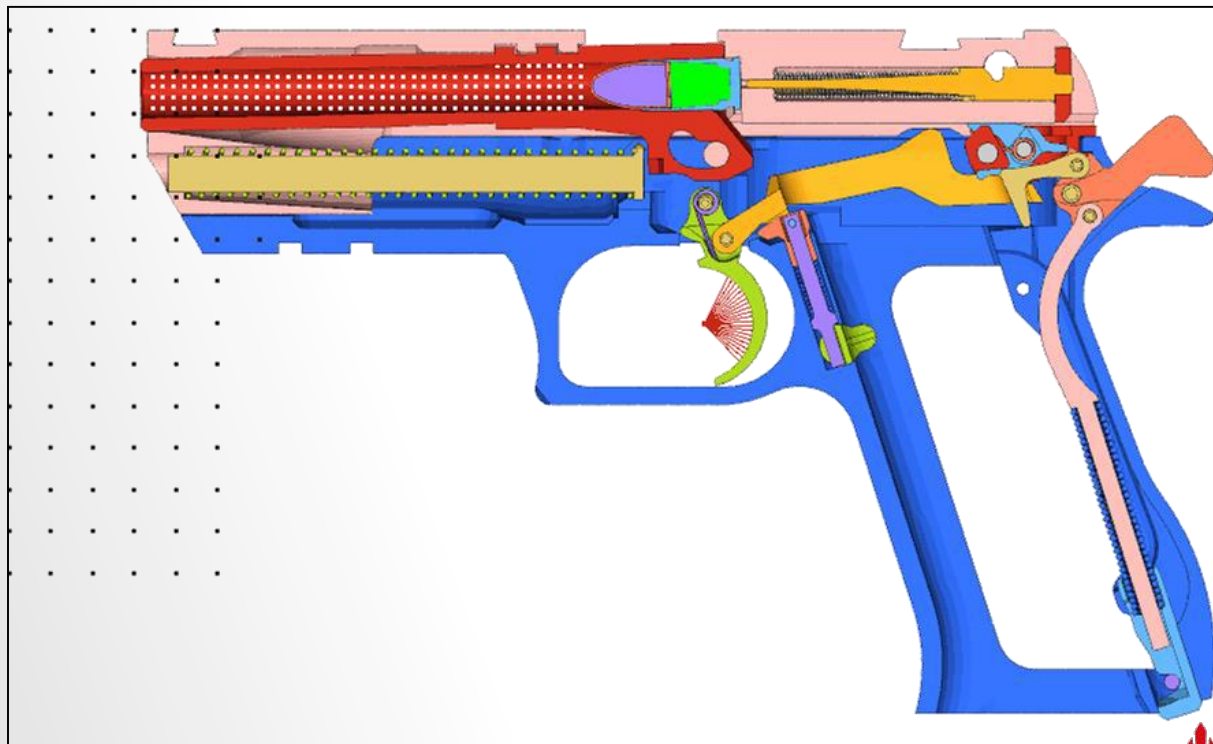
 Mat. calibration

 Spring calibration

 JWL calibration

 Running the job

- No of elements – 341576 (75% tetra, 25% Hexa / penta).
- No of nodes – 191521.
- No of components – 65.
- Type 7 contact – 19, mostly for sliding components and SPH components.
- Type 24 contact – 74, mostly for initially penetrated components.



Problem definition

Mat. calibration

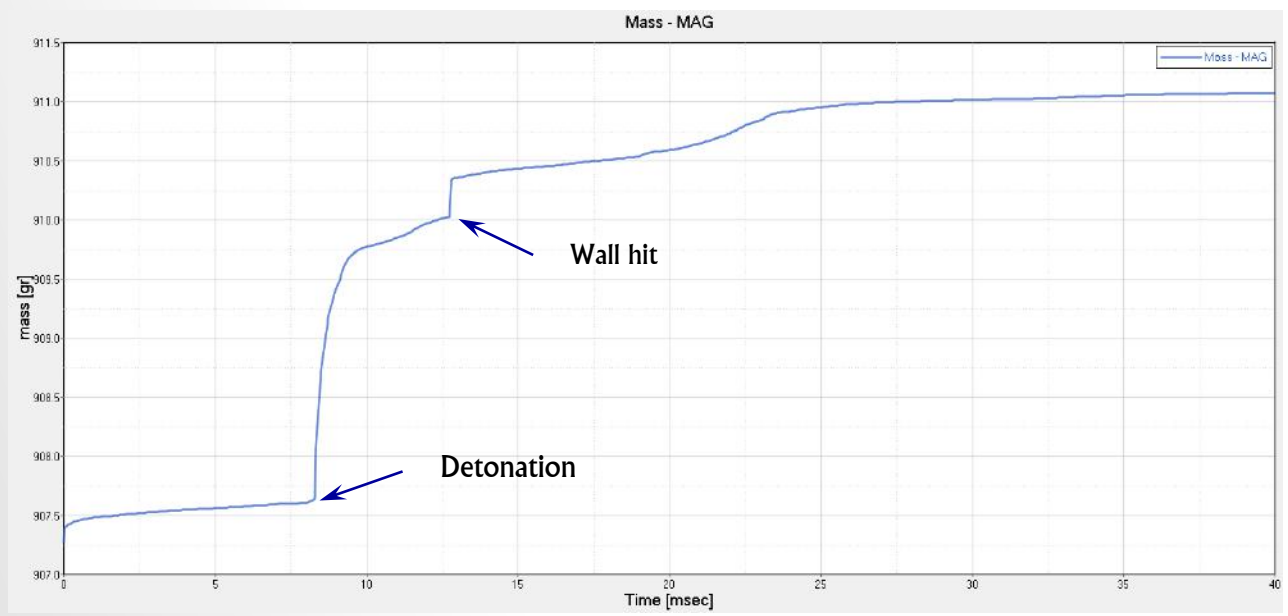
Spring calibration

JWL calibration

Running the job

- Smallest time step in the model – 5.8e-6 [msec]
- Time step is increase by 5.2.
- Minimum defined time step – 3e-5 msec (ENG\_DT\_NODA card is used for small mass scaling).
- Total mass added - 0.4%.
- Run time – 40msec at approx. 40Hrs.

$$\Delta t = L_c \cdot \sqrt{\frac{\rho}{c}}$$





Problem definition



Mat. calibration



Spring calibration



JWL calibration

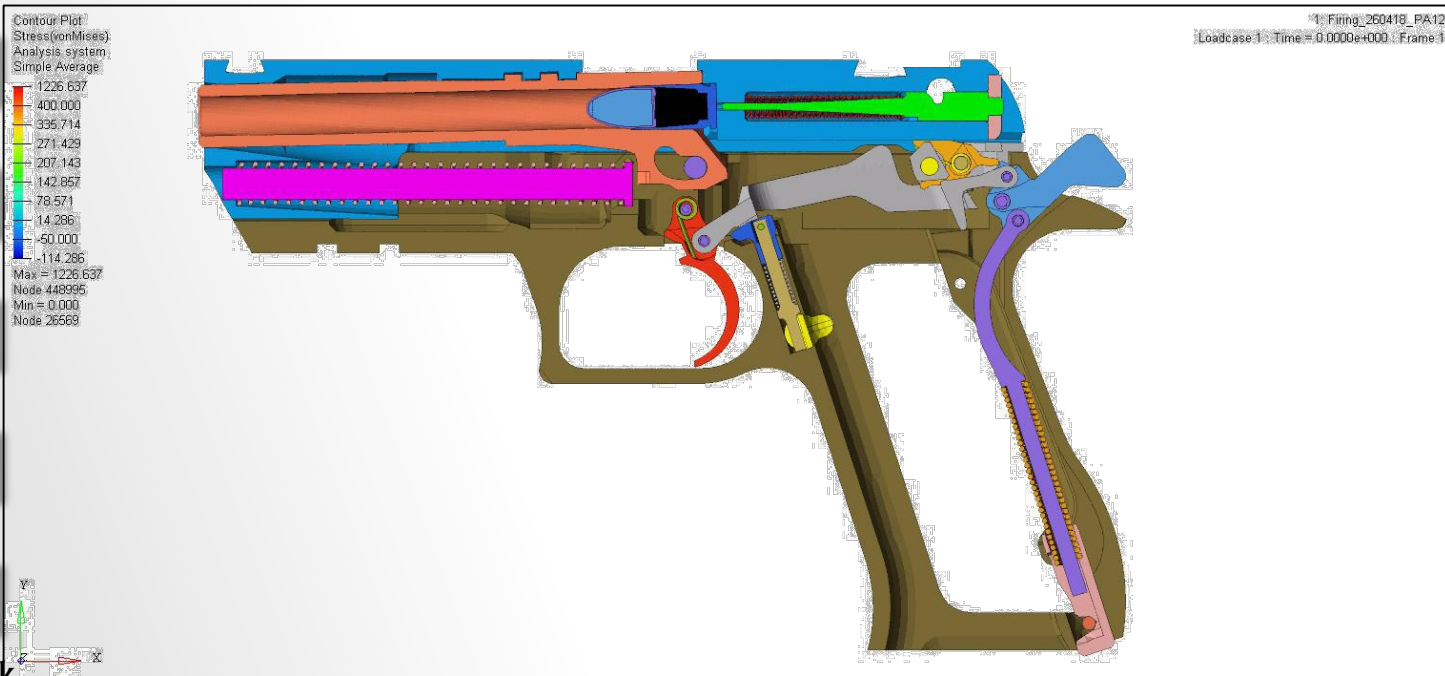


Running the job





Results


Reality check







 Problem definition


 Mat. calibration

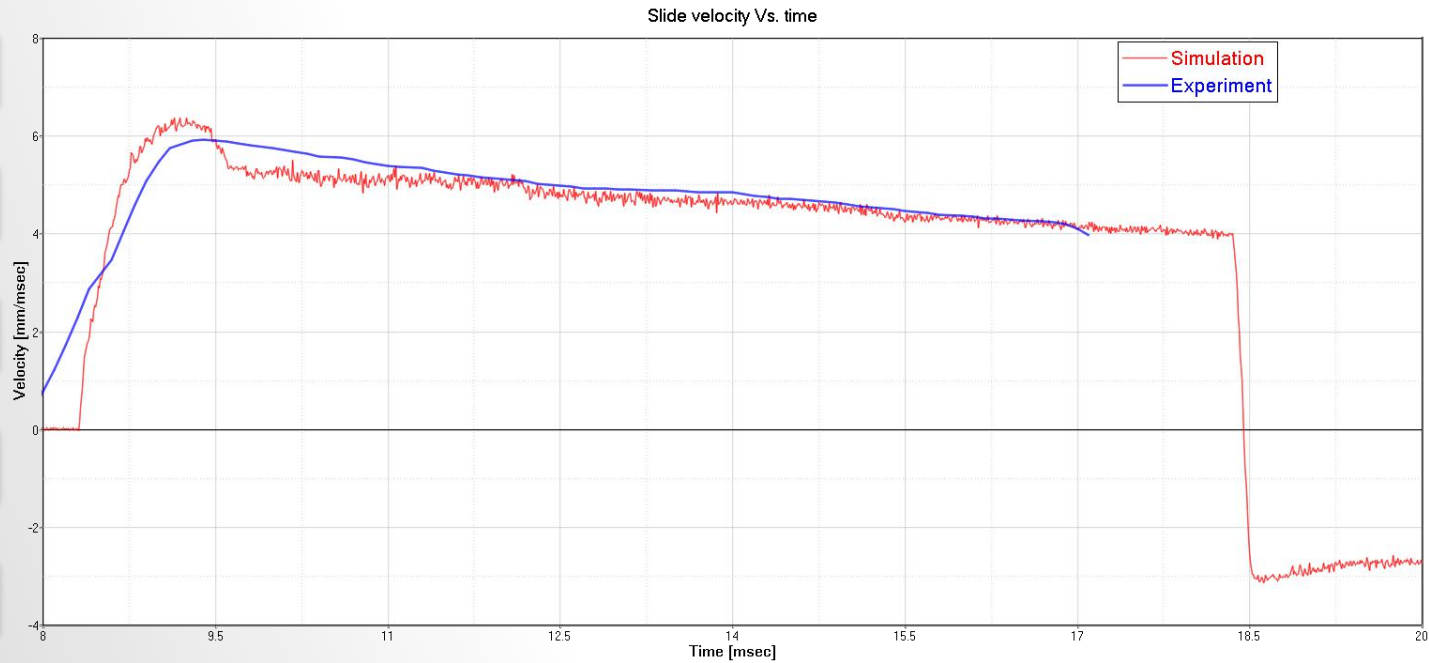
 Spring calibration

 JWJ calibration

 Running the job

 Results

 Reality check





Problem definition



Mat. calibration



Spring calibration



JWL calibration

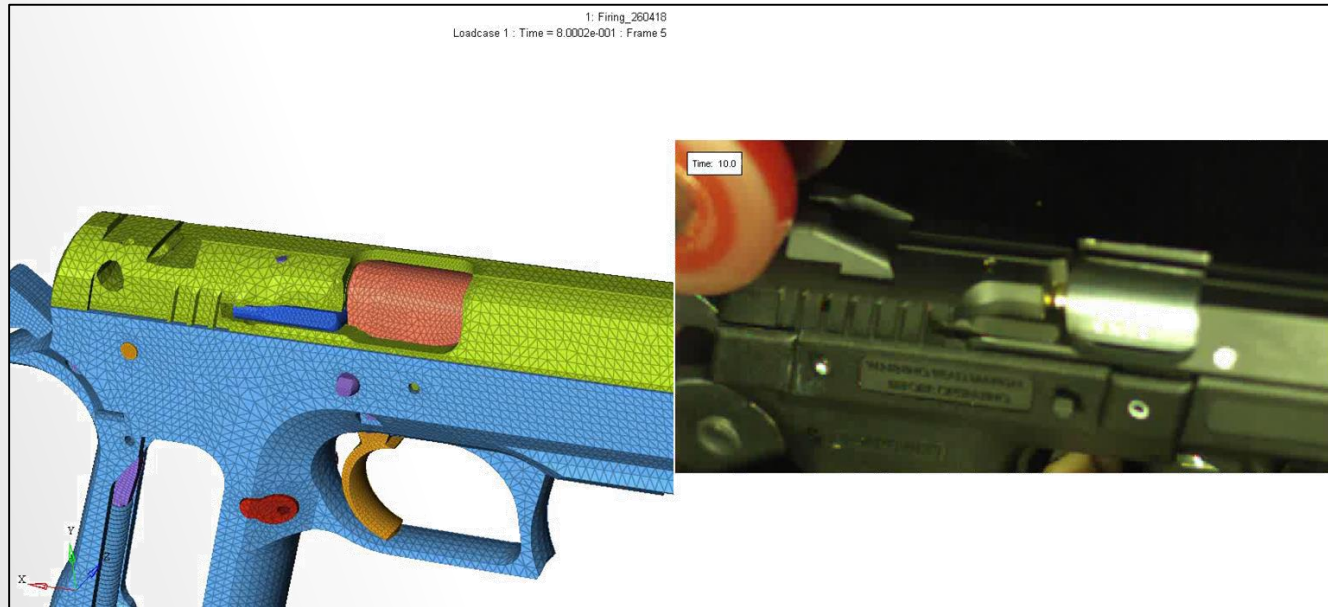



Running the job





Results


Reality check




 Problem definition

 Mat. calibration

 Spring calibration

 JWL calibration

 Running the job

 Results


 Reality check


 Hit and rendering










 Problem definition

 Mat. calibration

 Spring calibration

 JWL calibration

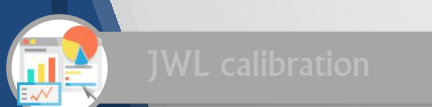
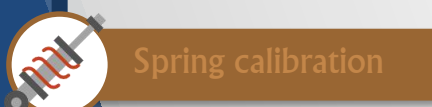
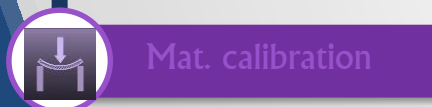
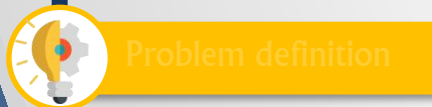
 Running the job

 Results

Reality check

Hit and rendering





- Excellent, and, comparable to reality results.
- HyperStudy knowhow created.
- JWL material created for future projects and developments.
- Material contact and general modeling workaround created.

# That's it

Thank you for your time and attention!

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[konstantina@iwi.net](mailto:konstantina@iwi.net)

## References:

- Mechanical properties at high strain-rate of lead core and brass jacket of a NATO 7.62 mm ball bullet L. Peroni<sup>1</sup>, M. Scapin<sup>1</sup>, C. Fichera<sup>1</sup>, , A. Manes<sup>2</sup>, and M. Giglio<sup>2</sup>
- GUNSHOT EFFECTS SIMULATION Mário ŠTIAVNICKÝ, Peter LISÝ
- <https://www.impetus-afea.com/support/documents/?doc=explosives&page=contents>
- <https://iwi.net/>