4-11-2014

Deformation of 2024-T3 Aluminum at High Strain Rates

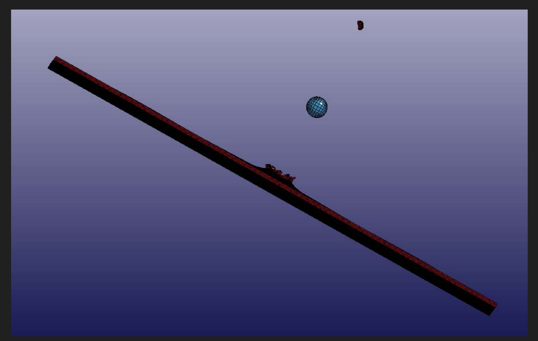
Chris Seto

Deformation and Failure of 2024-T3 Aluminum at High Strain Rates

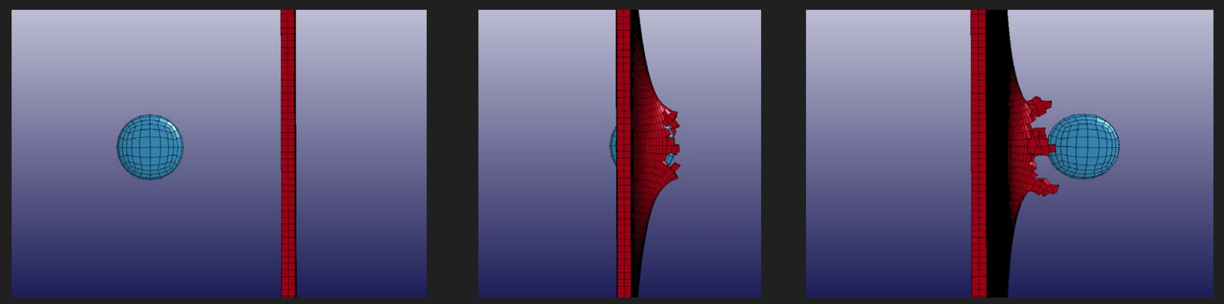
By Chris Seto
Faculty Mentor: Dr. Roger Veldman

Projectile Impact

Computer Modeling

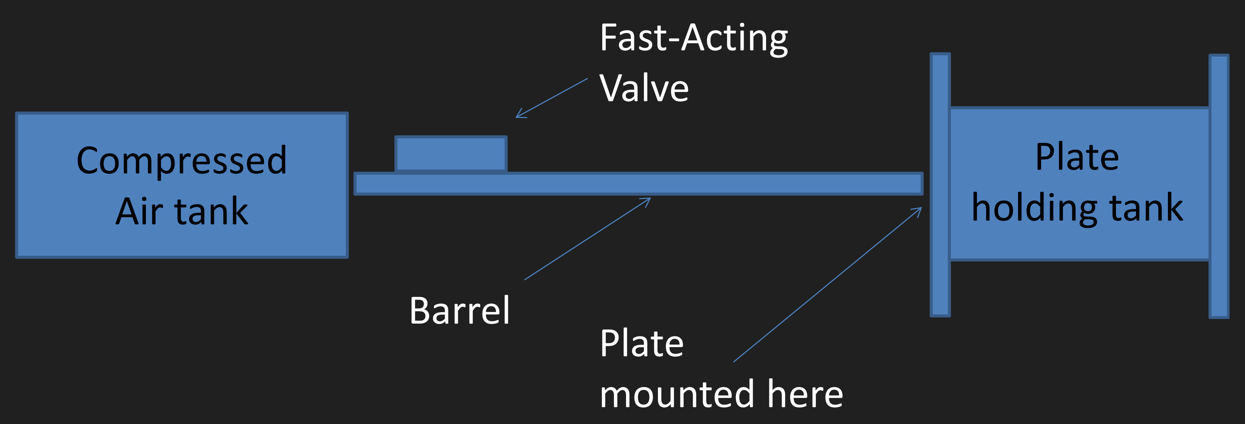


- Software used in modeling was LS-dyna, a program commonly used in crash test simulations.
- LS-dyna uses finite element analysis, meaning that physical realities (the ball and the plate) are meshed and each block of the mesh (element) is analyzed discretely over a series of time steps.
- The finer the mesh, generally the more accurate the simulation is.
- Three different mesh sizes were used in modeling the plate:
  - 120 x 120 x 1 elements
  - 240 x 240 x 2 elements
  - 360 x 360 x 3 elements
- Simulations were usually run in order to measure residual velocity (projectile velocity after plate penetration) because this was not possible with the experimental set up.
- It was also possible to observe the failure pattern of the plate and compare to experimental results.



Before impact — During impact — After impact

Experimental



- Used compressed air to fire 0.25 inch diameter steel spheres into 7 inch x 7 inch aluminum plates held in place around the edges by 0.5 inch clamps leaving a 6 inch x 6 inch surface available for impact.
- Plates with thicknesses of 0.032 inches, 0.05 inches, and 0.063 inches were used.

- Failure patterns of the plate and ballistic limit were studied and compared against LS- dyna's results in order to calibrate computer models.

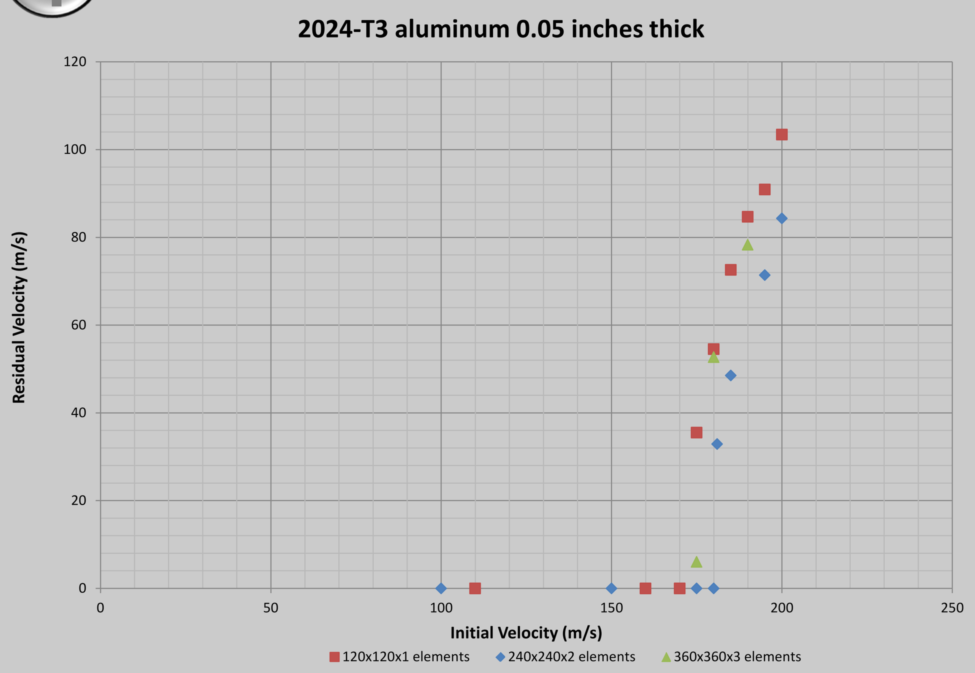
Plugging Failure

Petaling Failure

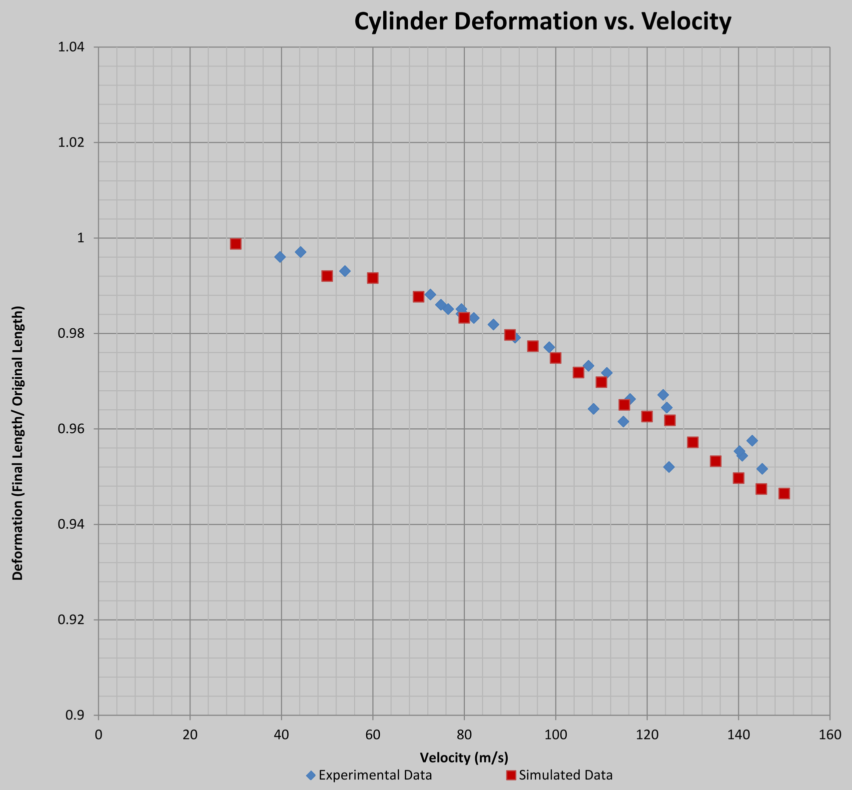
Abstract

This Project's goal was to study the deformation and failure pattern of 2024-T3 aluminum under high strain rates and to validate the numerical analysis of the aluminum's deformation and failure using experimental testing. This topic is relevant because of its use in aircraft safety in the event of an onboard explosion. The study of the aluminum was approached using two different methods. The projectile impact test involved shooting a hardened steel sphere at a clamped plate of the aluminum. Then the ballistic limits of various thicknesses of aluminum and the plate failure patterns could be examined. In the Taylor cylinder test, cylinders of the aluminum were shot at a hardened and immovable disk. The cylinders were measured before and after impact and the deformation was correlated with velocity. The results from the computer modeling were closely aligned to the experimental data when a Johnson Cook material model, a model that incorporates differing strain rates, was used in the simulation. Therefore, a Johnson Cook model of 2024-T3 aluminum is a viable source of data when used in this kind of computer modeling.

Results



- Initial and residual velocity was measured for several different 0.05 in. thick plate simulations. These measurements were used to find the simulation's ballistic limit, the velocity at which the slug will completely penetrate 50 % of the time.
- These results (shown on the graph above) were compared to the experimentally determined ballistic limit which was determined to lie between 184 m/s and 188 m/s.
- The finest meshed computer model predicted that the ballistic limit would occur at 174 m/s.
- There was a maximum error of 14 m/s which is equivalent to an error of 7.4%.



- Solid Cylinders were impacted with a rigid surface across a range of velocities. The deformation was compared to simulated cylinders impacted at similar velocities. The results are shown in the table above.

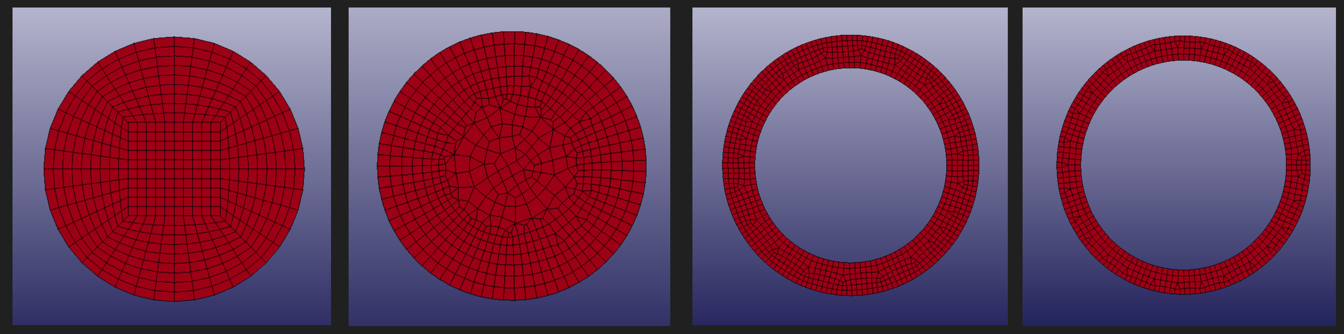
<u>Conclusions</u>

The Johnson Cook material model used in modeling the aluminum plate produces similar results as experimental testing in both the projectile impact experiment and the Taylor Cylinder test. Therefore, it is a valid model for use in future testing.

Taylor Cylinder

Computer Modeling

- A finely meshed and a coarsely meshed solid cylinder were both created in LS-dyna.
- Two different hollow cylinders were also simulated, one with a wall thickness of 0.8 mm and the other with a wall thickness of 0.6 mm.

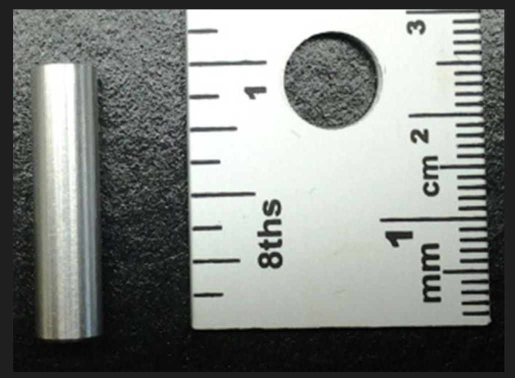


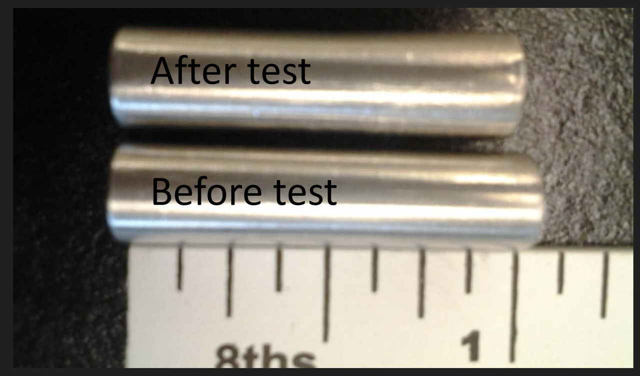
Coarse mesh solid (36800 elements) — Fine Mesh Solid (92850 elements) — 0.8 mm Hollow — 0.6 mm Hollow

- Cylinders were parameterized to be exactly 1 inch long and then impacted with a rigid wall. Afterwards, their deformed length was compared to their original length.

Experimental

- Cylinders were very exactly machined and then impacted on a hardened steel disk.
- Velocity was stepped across a range from 40 m/s to 150 m/s and the results were compared to the computer simulation.





Future Goals

Now that a valid material model for 2024-T3 Aluminum at high strain rates has been tested in simple simulations, the next step is to use it in more complex scenarios. One possible future investigation is a study into the effect of combined blast loading and fragmentation. On 2024-T3 aluminum.

Other future areas of study include experimental testing with the hollow Taylor Cylinder and the effect of pressure-loading on the aluminum plate prior to impact.

Acknowledgements

- Hope College
  - Engineering Dept.
  - Natural and Applied Sciences
  - Dr. Roger Veldman, faculty advisor
  - Ty Daugherty, building air cannon
- Dept. of Homeland Security, loaning high-speed camera