American Axle & Manufacturing (AAM) utilizes Engineered Abrasives (EA) shot peening equipment to induce compressive residual stress (CRS) in gear parts. The project aims to investigate and model/simulate induced stress states of Almen strips and AAM gear parts over a variety of applicable peening conditions. Good comparisons between the experimentally measured and computer-generated models of the CRS were found.

**Project Introduction**
- Shot peening introduces CRS on and immediately below the treated surface to increase fatigue life.
- Almen strips are used to test shot peening parameters in situ.
- The induced CRS on the strip causes bending, measured as the maximum arc height.
- The simple geometry means CRS can be measured with XRD.
- Due to the complex geometry, stress in axle gear parts can be significantly more difficult to measure.

**Experimental Methods/Results**

### Experimental Data Analysis

![Experimental Stress Depth Profiles](image)

As pressure increases:
- The depth of compressive layer increases.
- The stress peak maximum is lower and shifted deeper.

As flow rate increases:
- The depth of compressive layer decreases.
- The stress peak maximum is higher and shifted shallower.

At high peening intensities:
- Experimental profile depth and maximum residual stress demonstrate convergence to an average residual stress value.

### Simulation Development

To create a simulation of the shot peening process, the ABAQUS finite element modeling software was used. A simple 2-D model was developed into a complex 3-D model accounting for particle size distributions.

- Simulation input files were created through an ABAQUS input file generation script that was written as part of the scope of this work.
- The input file script reads shot particle size data, as collected from a CANTY Solidizer particle measurement system.

**Experimental Residual Stress Depth-Profile Results**

**Experimental Stress-Depth Profiles**

![Graphical representation for Weibull statistical fits for cumulative work (left) and stress-depth (right).](image)

**Comparable Results**

**Material and Processing Conditions**

### Almen Strip Information

- **Material**: 1070-Steel
- **Thickness**: 0.785 mm, 1.295 mm, 2.385 mm

**Simulation Results**

**Velocity Sensitivity Study**
- Both total work and cross over depth increase as a function of velocity, for a stress state taken at the center of a single impact.

**Multiplicity Sensitivity Study**
- Suggests that convergence in stress state is reached after 8 impacts in the same location.
- Damage to the substrate begins to occur after 16 subsequent impacts.

**Conclusions/Recommendations**

- According to the experimental results, the stress state quantified by the cumulative work shows convergence between standard, high blast pressure, and flow rate parameters.
- Preliminary simulations of axle gear geometries show a clear compressive stress layer at the root of the gear. On the substrate’s blind face, most peening will occur through secondary impacts.
- There is a qualitative agreement between simulation and experimental results for the induced stress state in Almen strips. CW28 shot induces the deepest compressive layer with the highest maximum compressive stress.

**Future Work**

Correlation between the experimental and simulation results can be improved through characterizing and validating the material properties of both Almen strips and axle gear components. Further development of sensitivity studies on the relationship between coverage percentage and stress state could also inform further simulations.