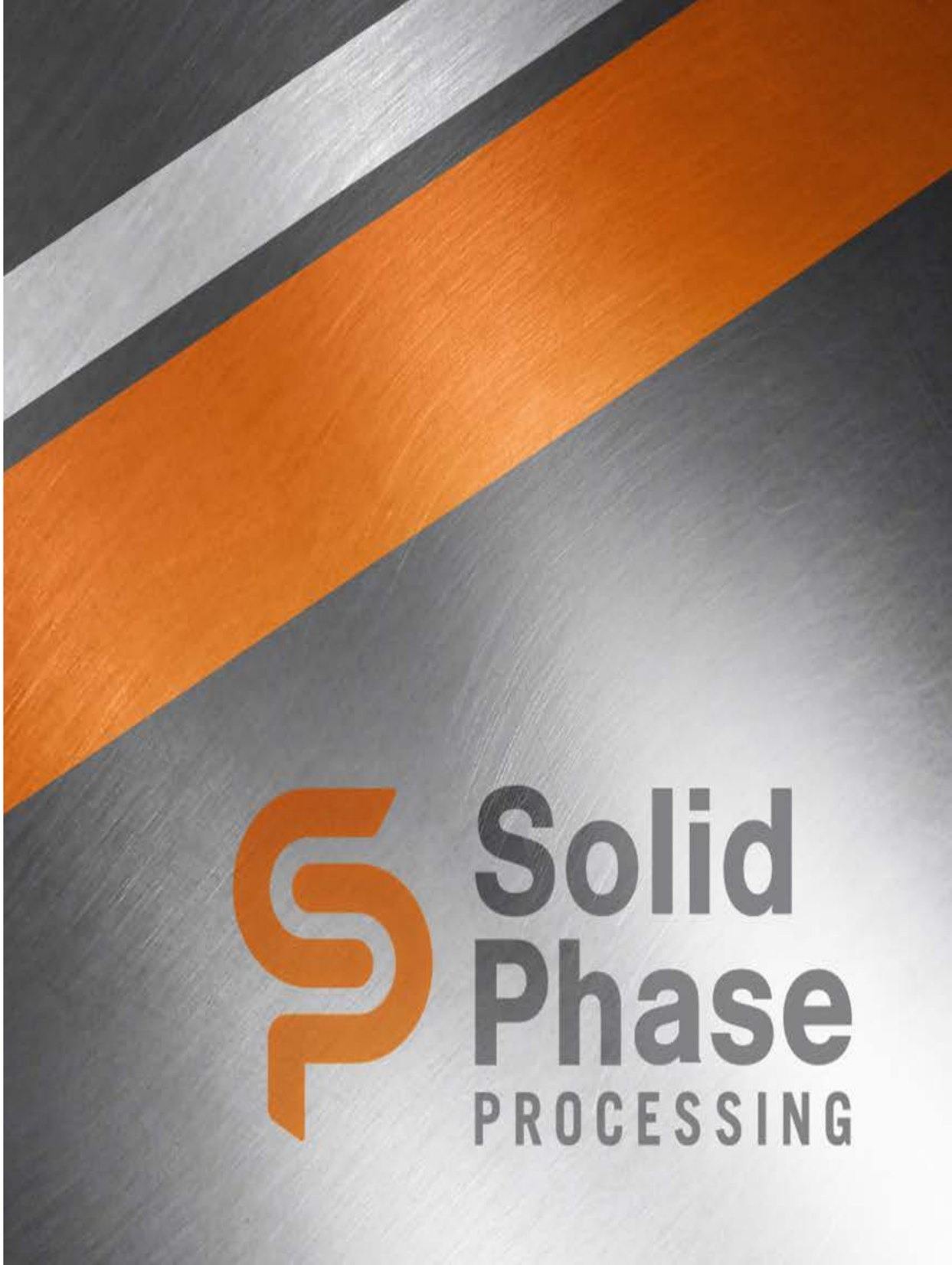
Non-Rare Earth Magnesium Bumper Beams

Presenter: **Darrell Herling[1]**
Position: **Manager**
PM/PI: Scott Whalen[1]
Team: Md. Reza-E-Rabby[1]
Dalong Zhang[1]
Jens Darsell[1]
Tim Skszek[2]

[1]Pacific Northwest National Laboratory

[2]Magna International, Corporate R&D

Project ID#: MAT-149



Overview

Timeline

- Project start date: Jan. 2019
- Project end date: Dec. 2020
- Percent complete: 13%

Barriers

- Material technology roadmap for magnesium
  - Low cost feedstock
  - Improved alloys for energy absorption
  - Manufacturing of extrusions
  - 250 MPa yield strength and 15% elongation by 2025

Budget

- Total project funding
  - $1,000K ($500K/yr)
- $500K - DOE share
- $500K - Industry share

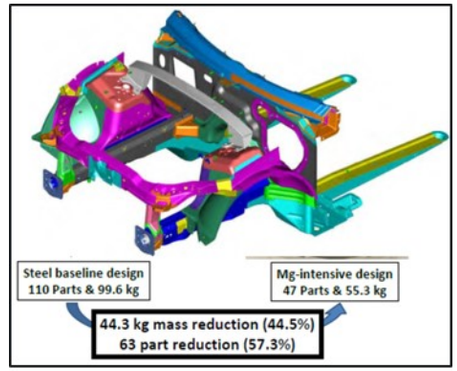
Partners

- Magna International
- Pacific Northwest National Laboratory (PNNL)

Relevance

- **Challenge**
  - Improved energy absorption in magnesium alloys
  - Lower cost materials and manufacturing pathways
- **Objective**
  - Develop Shear Assisted Processing and Extrusion (ShAPE) to fabricate ***magnesium extrusions with rectangular profile***
  - Eliminate costly rare-earth (RE) elements
  - Equivalent energy absorption relative to Al extrusion
  - Progress toward multi-zone extrusions
- **Benefit**
  - >30% weight reduction possible by replacing of aluminum bumper beams with magnesium alloy


Brittle failure of Mg in crush

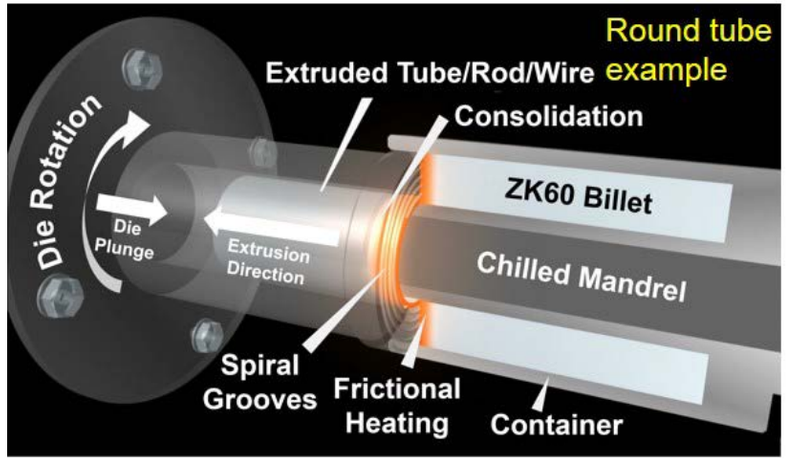


From DOE Magnesium Front End Research and Development (MFERD)

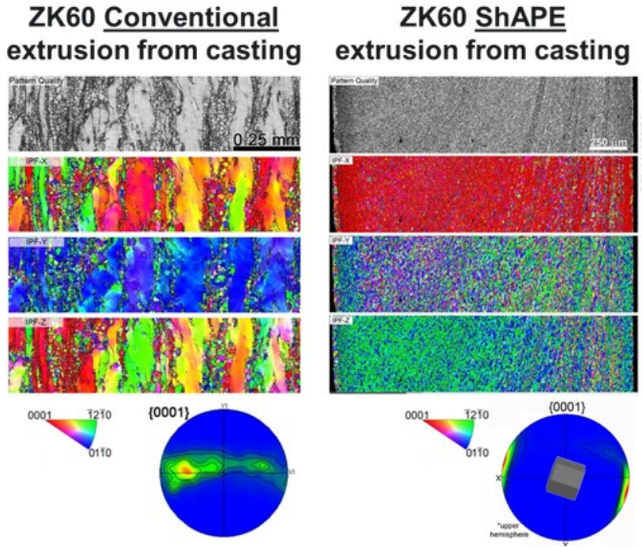
Approach - Background

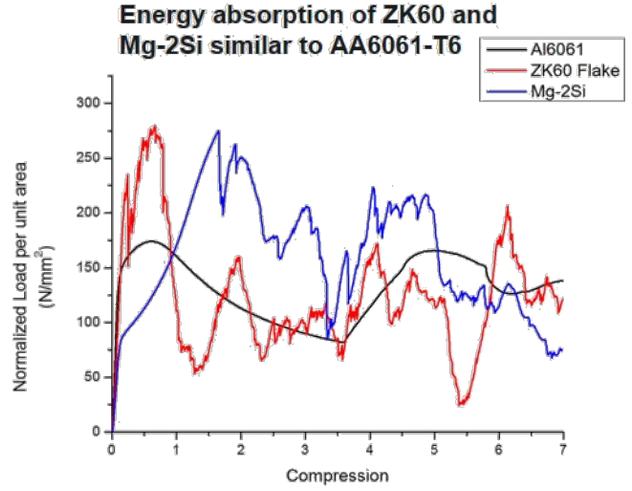
- **What is ShAPE?**
  - Scalable method of extruding materials with microstructures and bulk properties that cannot be achieved by conventional extrusion
  - Linear and rotational shear are combined to plasticize material without melting
- **This project will adapt ShAPE for rectangular hollow profiles**
  - ***Move from round tubes to non-circular profiles*** of interest in bumper beam applications
  - Adapt ShAPE for portal bridge die approach

- **Benefits of ShAPE for Mg**
  - Grain refinement and texture alignment
    - Eliminates asymmetry in tensile/compressive strength
    - Energy absorption of non-RE ZK60 equivalent to AA6061
    - >20% room temperature elongation
  - 10-20X reduction in ram force
  - Potential for industrial scale



Approach - Background



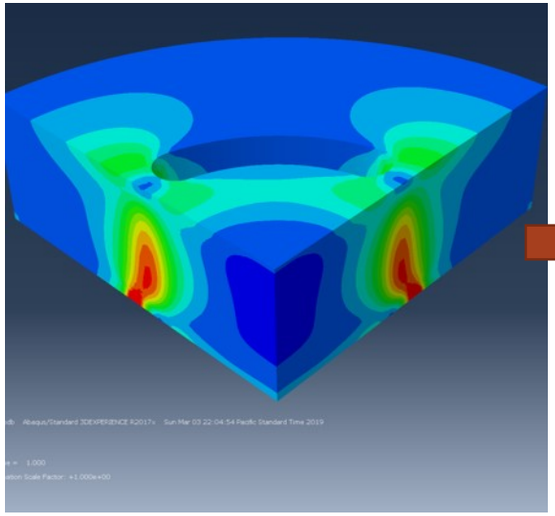


ShAPE extrusion enables non-RE Mg alloy ZK60 to attain energy absorption similar to AA6061

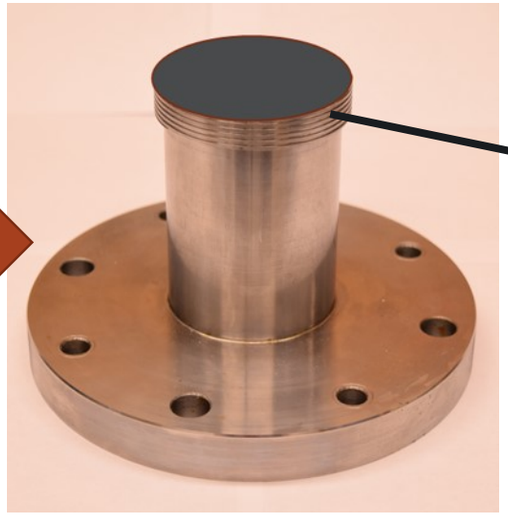
Progress to Date

- Project scope finalized on Jan. 3rd, 2019
- Project kick-off with PNNL and Magna in Richland, WA on Mar. 12th, 2019
- Task 1: Initiated die design process

Stress modeling for design of portal bridge die head



****Initial portal bridge die design for 0.5”x0.5”x0.06” wall**



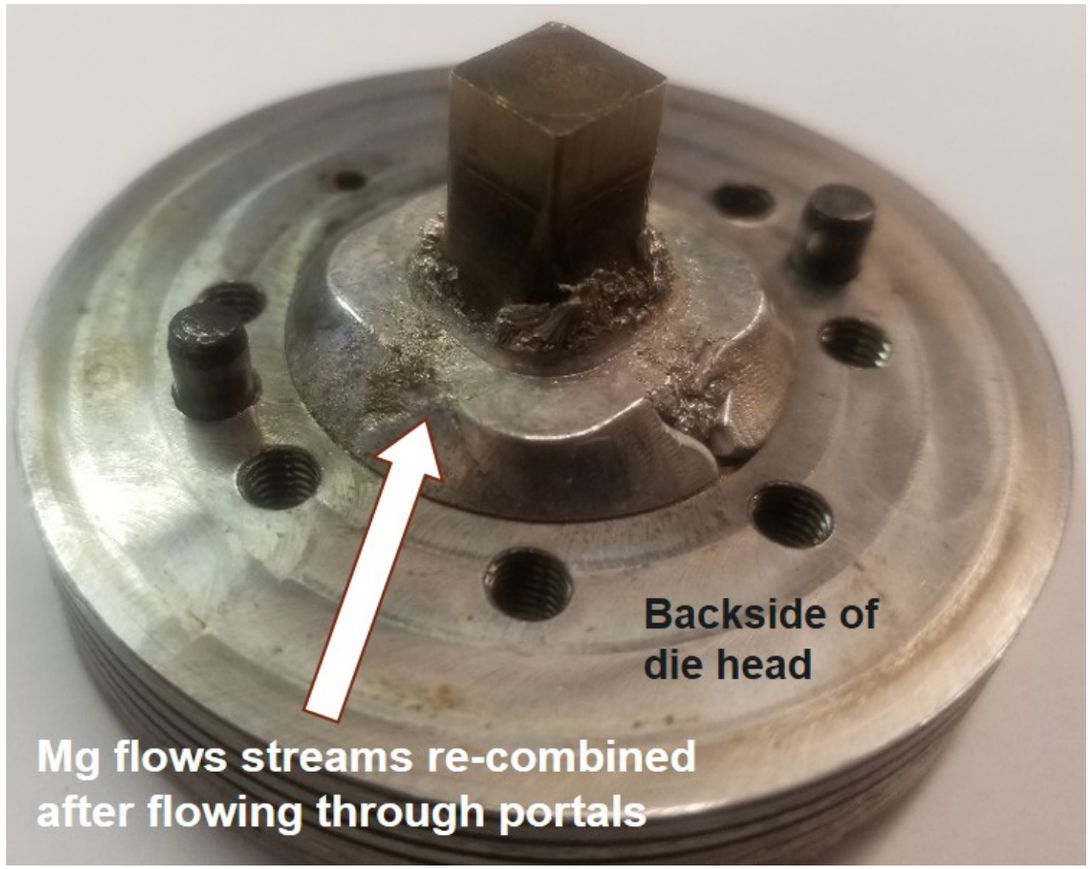
Underside of portal die head showing square mandrel

Work has begun on design of portal bridge dies for ShAPE extrusion of non-circular cross sections

****Patent-Pending PNNL Technology**

Progress to Date

Demonstrated that ZK60 can be re-combined in weld chamber after flowing through portals



- Die design variations underway to investigate the effect of die design features on material flow in weld chamber and around mandrel
- Magna will be conducting modeling and simulation efforts of material flow within the portal bridge die to aid in die design

Material re-combination shown for portal bridge die integrated into ShAPE process

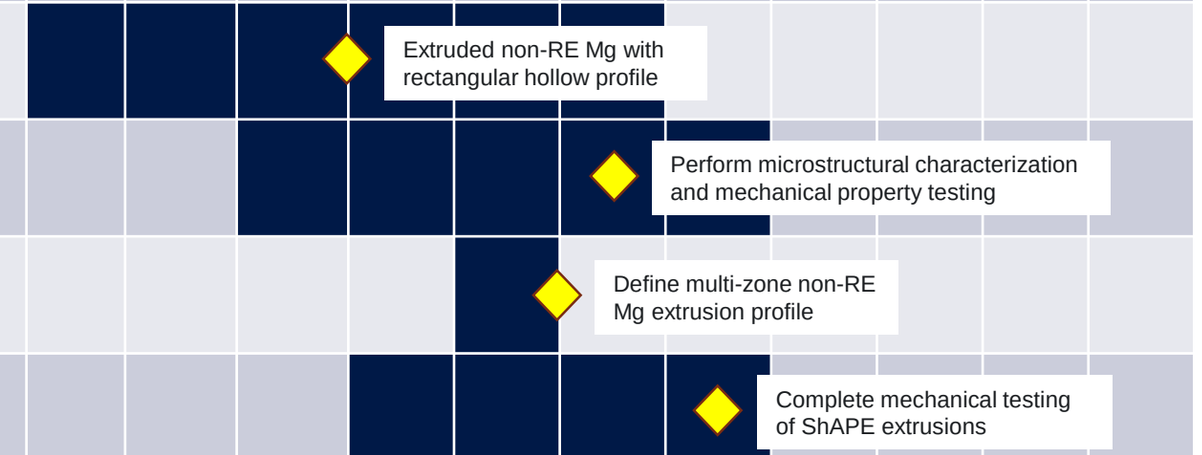
Collaboration

- **Pacific Northwest National Laboratory**
  - Scott Whalen (PI)
  - Md. Reza-E-Rabby (Die design)
  - Jens Darsell (Process development)
  - Dalong Zhang (Characterization)

- **Magna International**
  - Tim Skszek (PI)
  - Massimo DiCiano (Flow Modeling)
  - Mechanical testing of ShAPE extrusions
  - Design of extrusion profile geometry
  - Modeling of material flow in ShAPE extrusion dies
  - Extrusion Die Fabrication

Proposed Future Research

Task Number & Brief Description	FY2019				FY 2020				FY 2021			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1: ShAPE™ of Rectangular non-RE Mg Extrusions (PNNL Lead) Status: Underway												
Task 2: Characterization of ShAPE Extrusions (PNNL Lead) Status: Not Started												
Task 3: Definition of Multi-Zone Extrusion Profile (Magna Lead) Status: Not Started												
Task 4: Mechanical Testing of non-RE Mg Extrusions (Magna Lead) Status: Not Started												
Task 5: ShAPE™ of Multi-Zone non-RE Mg Extrusions (PNNL Lead) Status: Not Started												
Task 6: Project Summary (PNNL + Magna) Status: Not Started												



Proposed future work is subject to change based on funding levels

Summary

- **Relevance**
  - Improved energy absorption in Mg alloys
  - Lower cost materials and manufacturing
  - >30% weight reduction possible by replacing of aluminum bumper beams with magnesium alloy
- **Approach**
  - Develop Shear Assisted Processing and Extrusion (ShAPE) to fabricate non-RE magnesium extrusions with rectangular profile
  - Equivalent energy absorption relative to Al extrusion
  - Progress toward multi-zone extrusions
- **Accomplishments**
  - Project kick-off between PNNL and Magna on 3/12/19
  - Portal bridge die design underway – Joint effort between PNNL and Magna
  - Initial trials performed to demonstrate re-combination of flow streams in portal die