2012 NDIA
Joint Armaments Conference
May 14-17, 2012

Modeling and Analysis of a Cam for the 35mm Bushmaster® III Automatic Cannon

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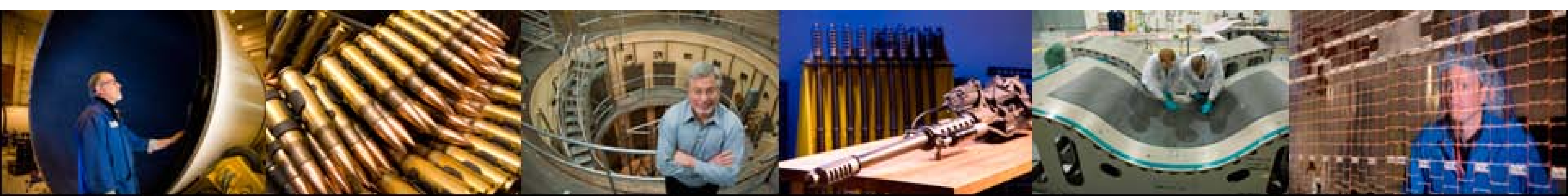


Outline

- Background
- Problem Statement
- Design and Analysis Process Overview
- Defining Cam Geometry
- Calculating Cam Loads
- Analyzing Cam Strains
- Conclusions

Background

ATK's 35mm Bushmaster® III (BMIII) Automatic Cannon:

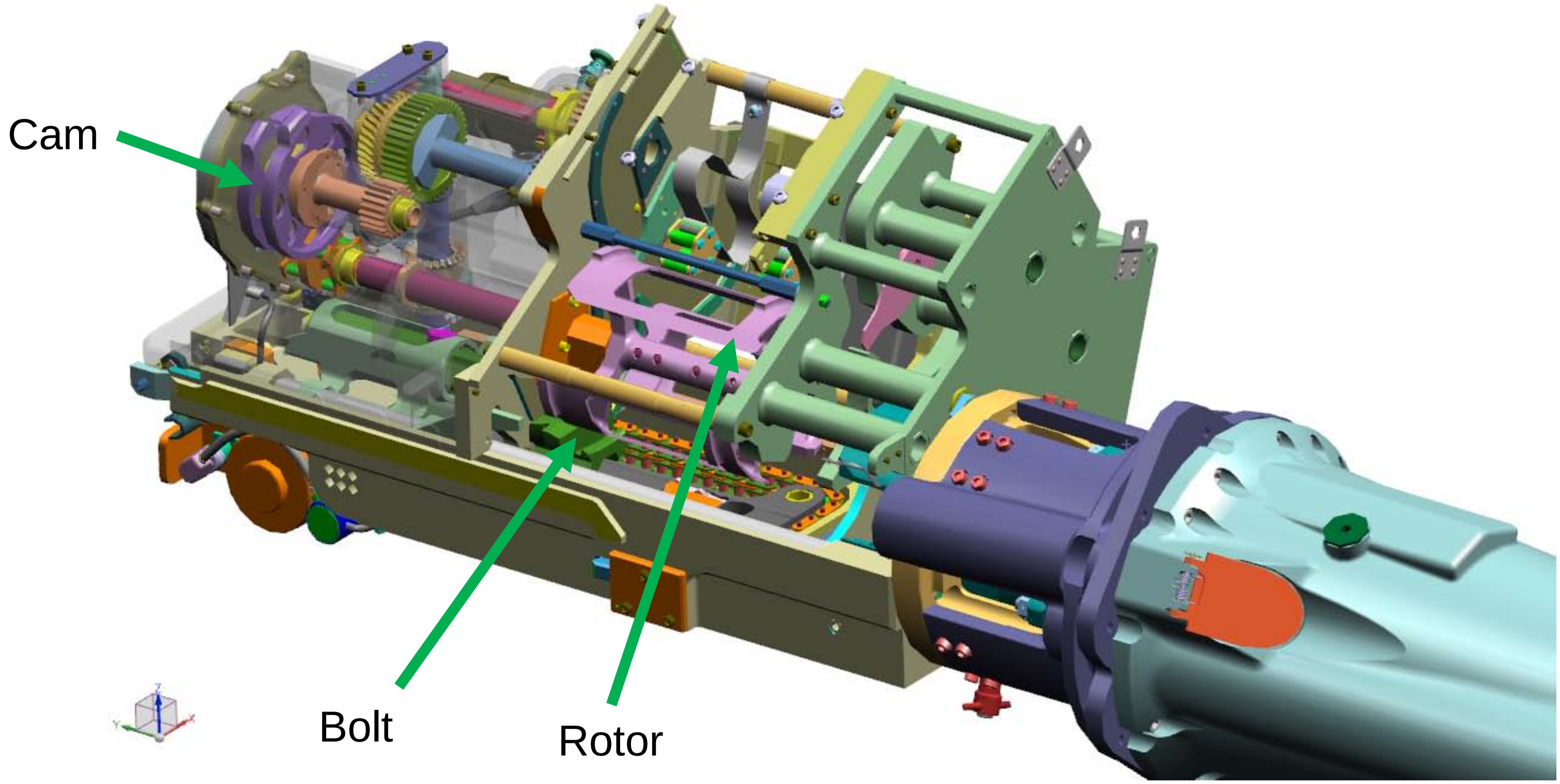
- Derived from 25mm M242 Bushmaster® Automatic Cannon and 30mm Mk44 Bushmaster® Automatic Cannon

Initial BMIII Development Testing Revealed:

- High Load Condition on the Ferguson Cam
- Large Permanent Deformation of the Cam Roller Follower

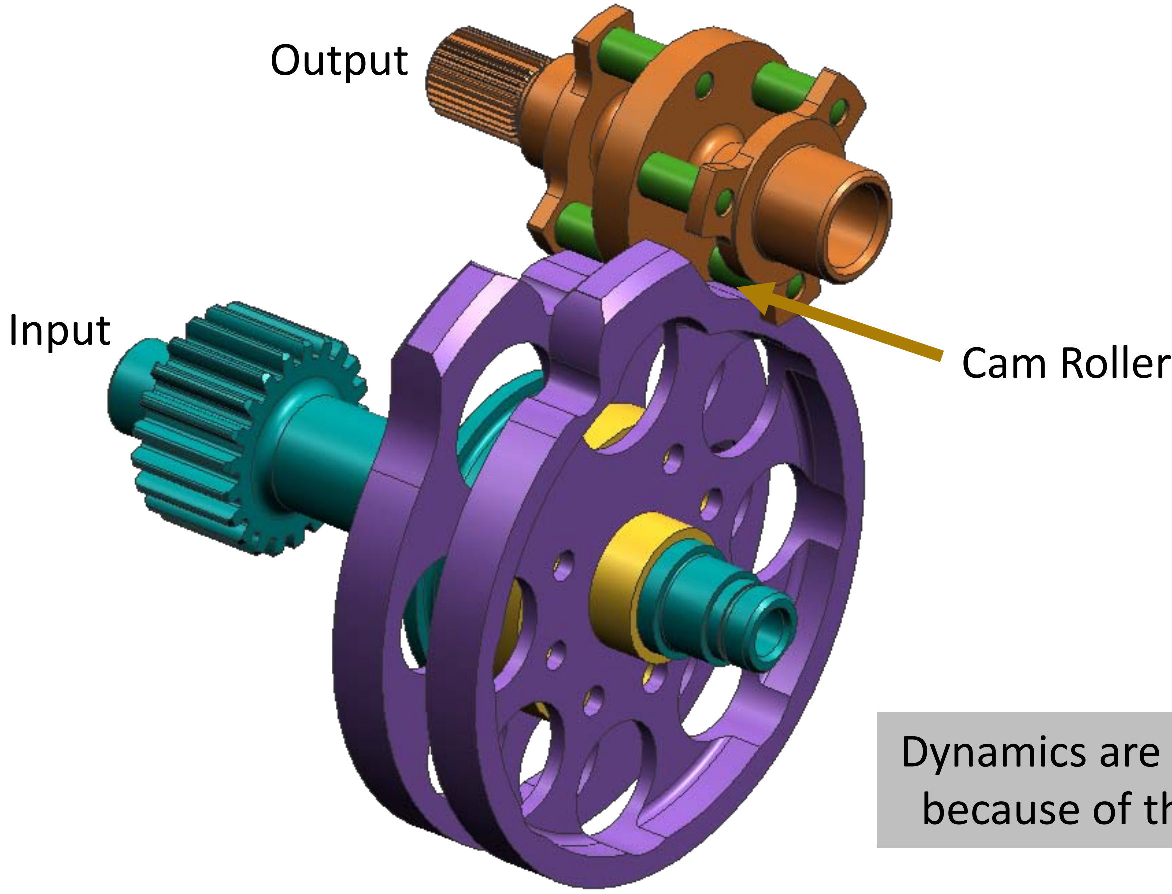
What is a Ferguson Cam?

Mechanism to Place Rounds onto the Breech Bolt Face



What is a Ferguson Cam? (p. 2)

Constant Velocity Input whose Output Turns a Rotor to Move the Rounds



Dynamics are similar to automotive cams because of the size of the ammunition.

Cam Rollers

Extruded Material

Early BMIII Development Testing

Example of Drastically Reduced Extrusion

With Production Material Selection

Problem Statement

Analysis Objectives:

1. Evaluate Material
2. Explore Options to Reduce Load While Minimizing Design Impacts

Starting Point:

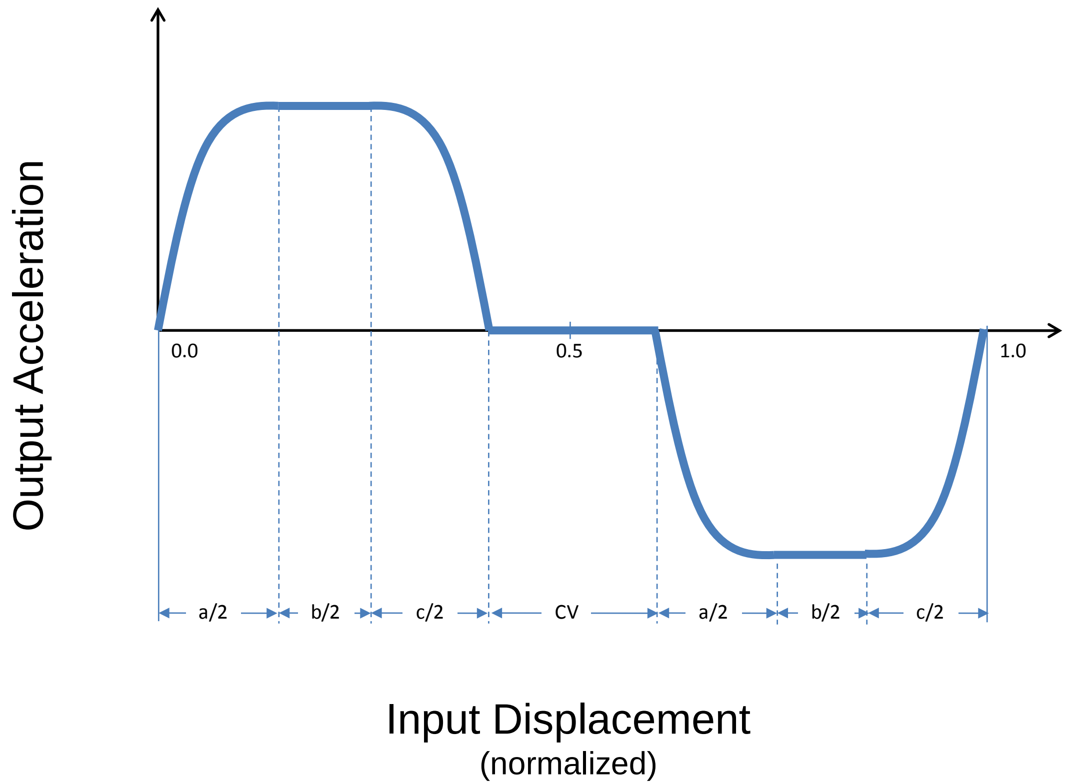
1. Cam Designs Traditionally Provided by Ferguson Cam Developers
2. Twelve Month Lead Time for New Cam Drawings
3. No Solid Models Available

Design and Analysis Process

- **Model the Geometry**
  - Mathcad: Create Input / Output Function (Displacement, Velocity, …)
  - Mathcad: Construct Cam Surface Data Points
  - NX: Create Geometry
- **Calculate Impact Loads**
  - MSC.ADAMS: Dynamic Model of Feeder System
- **Calculate Roller Stresses**
  - Abaqus: Transient Dynamic FEA with Contact and Nonlinear Materials

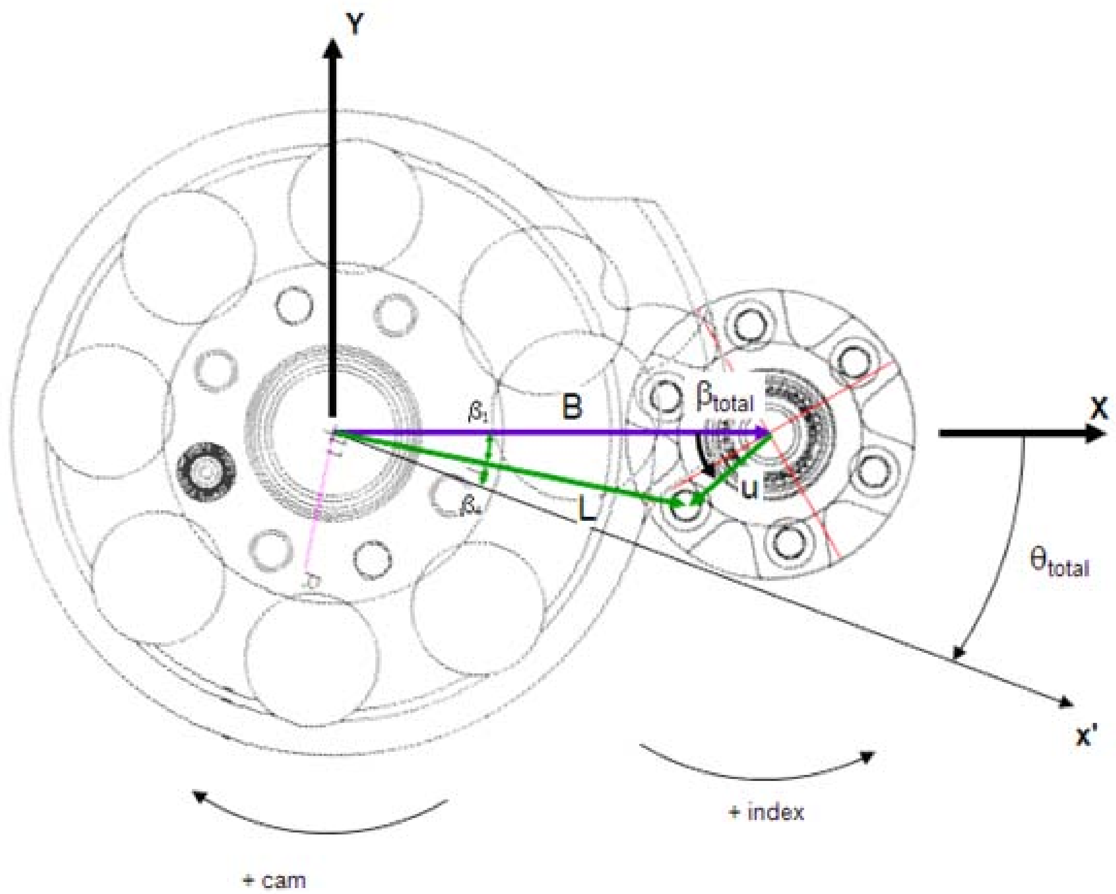
Define Geometry – Step 1

Choose an Input / Output Function

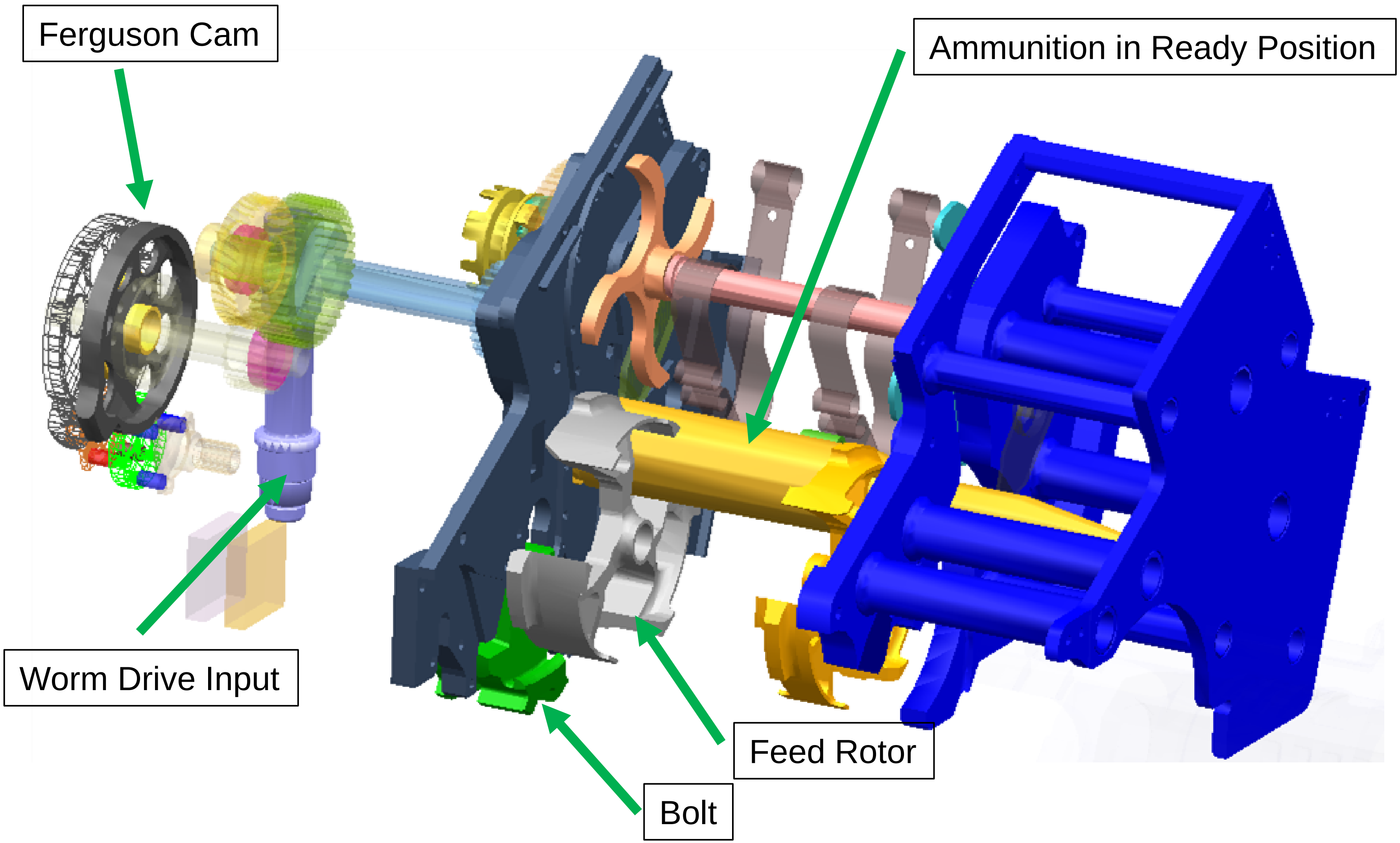


Define Geometry – Step 2

Basic Machine Design: Vector Diagrams to Define Component Motion



MSC.ADAMS Model – Static View



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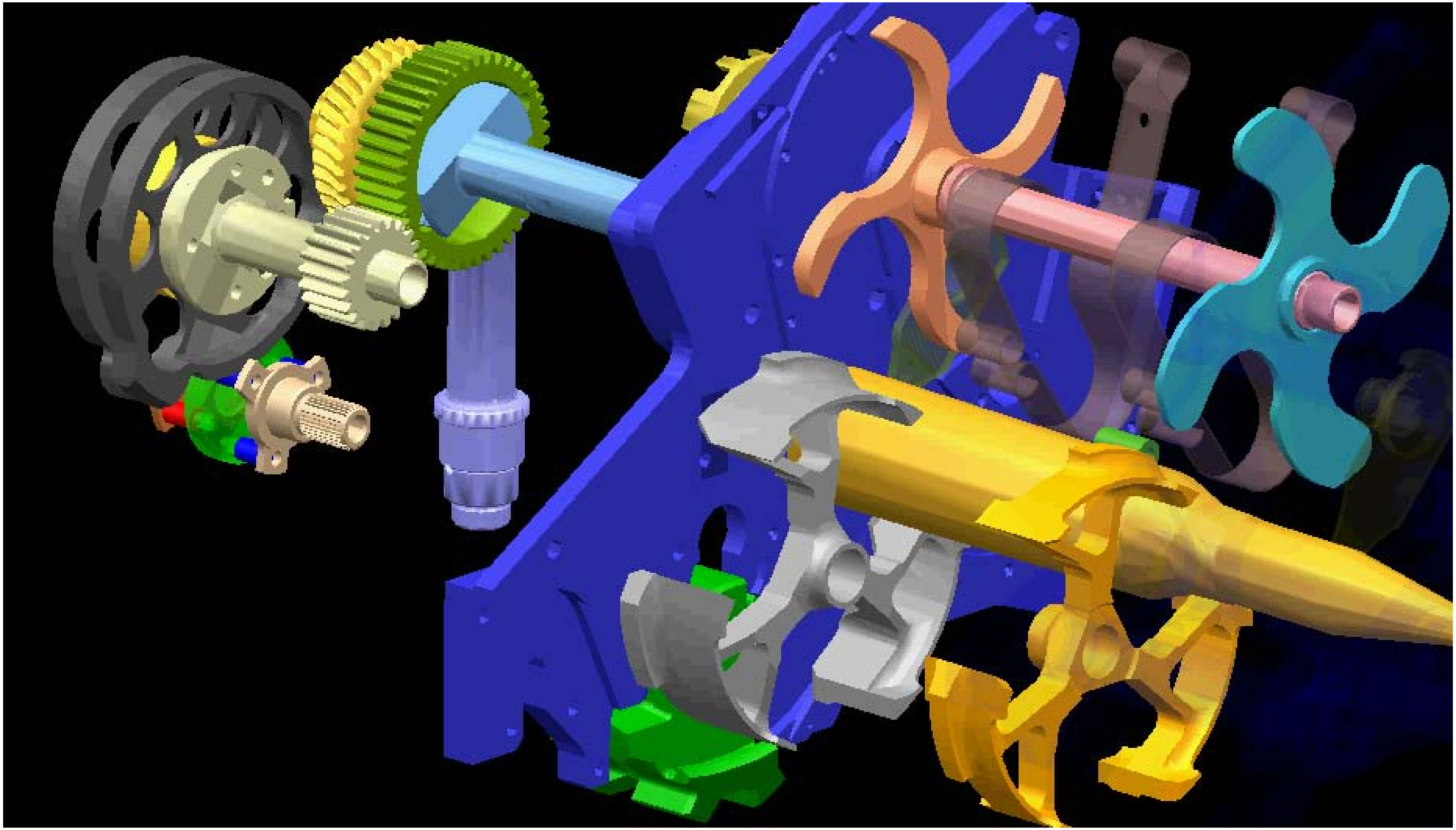
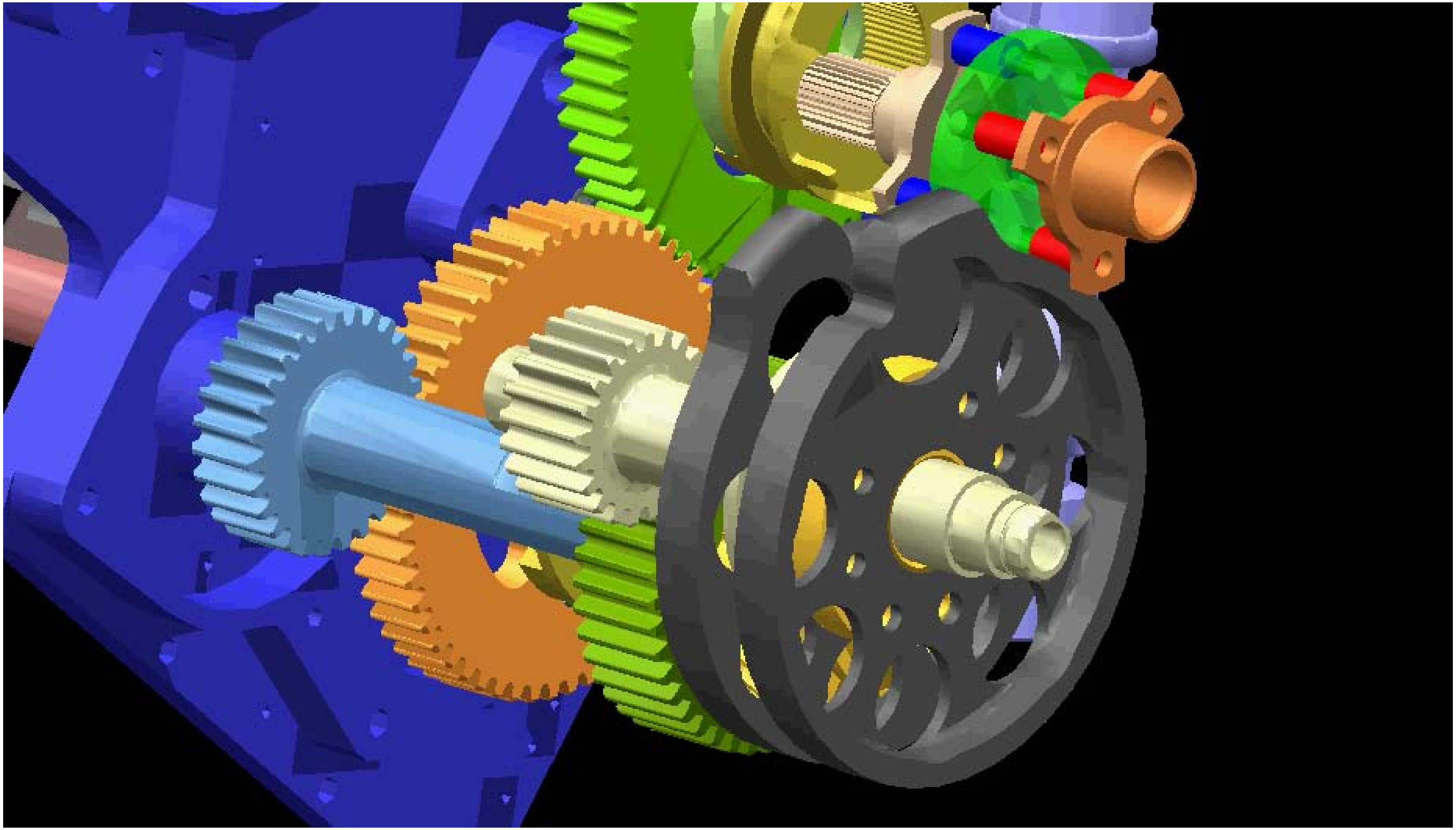
MSC.ADAMS Model – System Animation



MSC.ADAMS Model – Cam Animation



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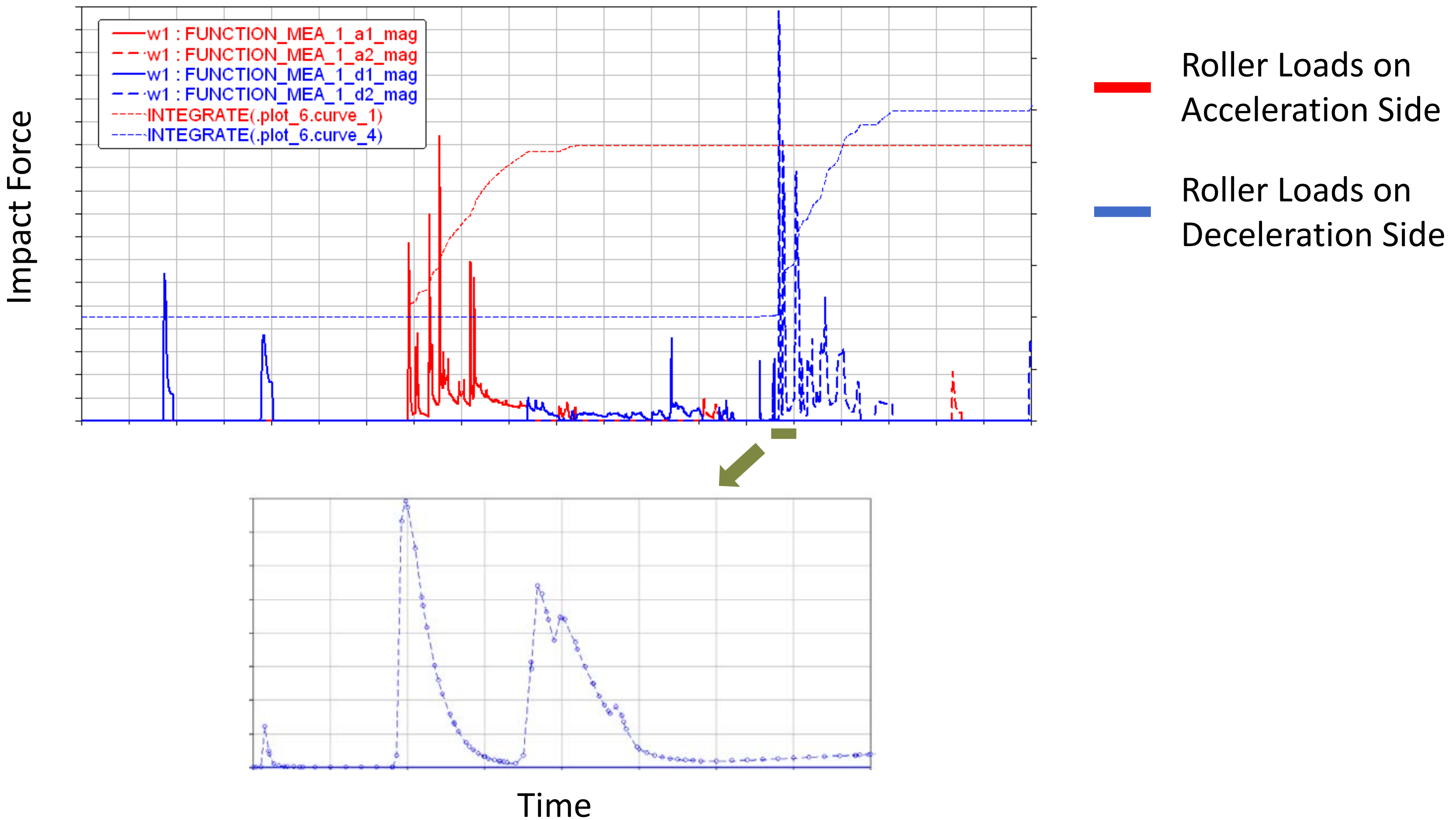
Calculate Roller Loads

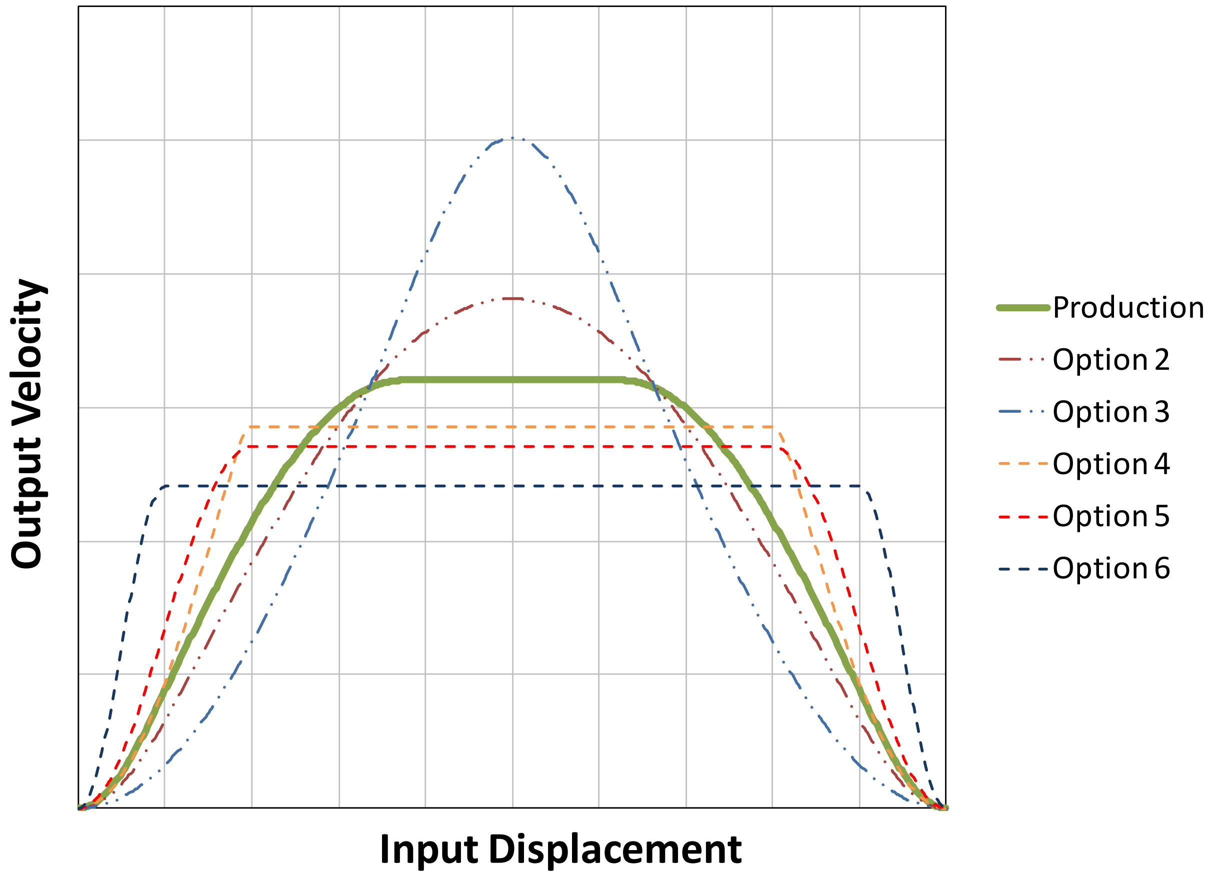
Impact Loads between Cam Rollers and Cam Face



Cam Function Iterations

Explore Changing Cam Acceleration Profile to Reduce Roller Impact Loads

- Leave Gun Envelope Unchanged (Cam Action Time and Size Unchanged)



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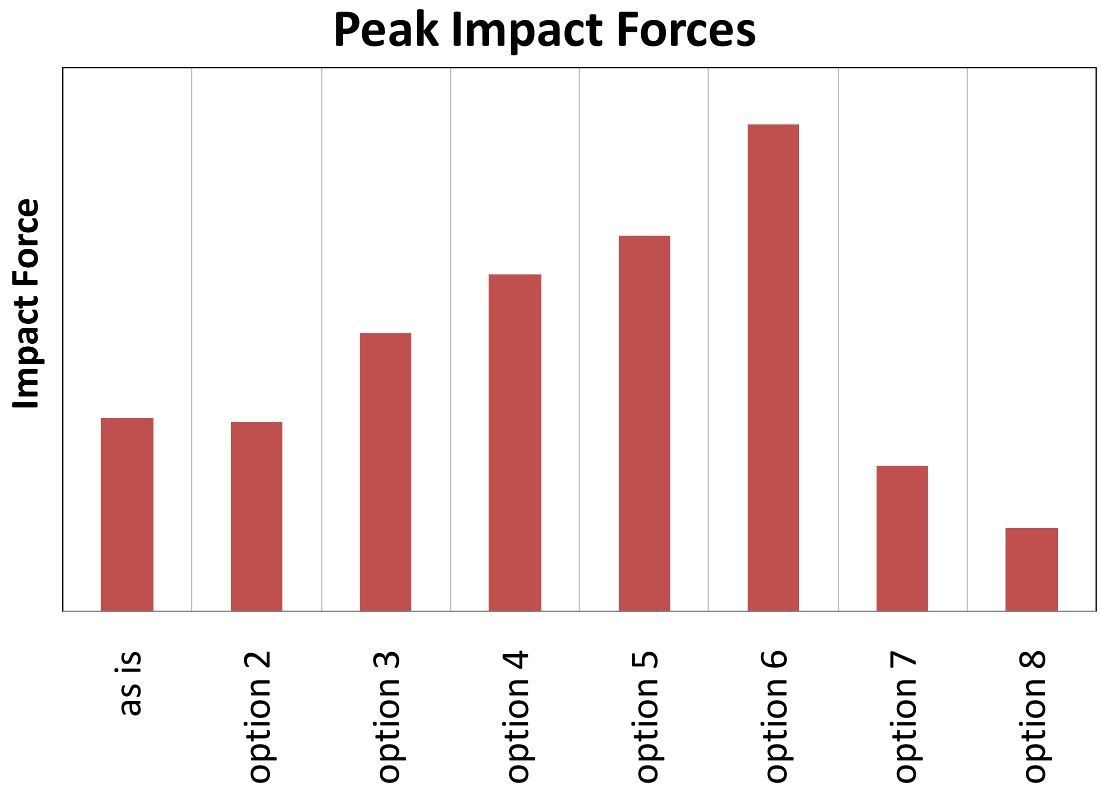
Cam Function Iterations – Results

Options 2-6: Change Cam Acceleration Profile, Leave Cam Size Unchanged
Options 7-8: Use Production Cam Acceleration Profile, Change Cam Size

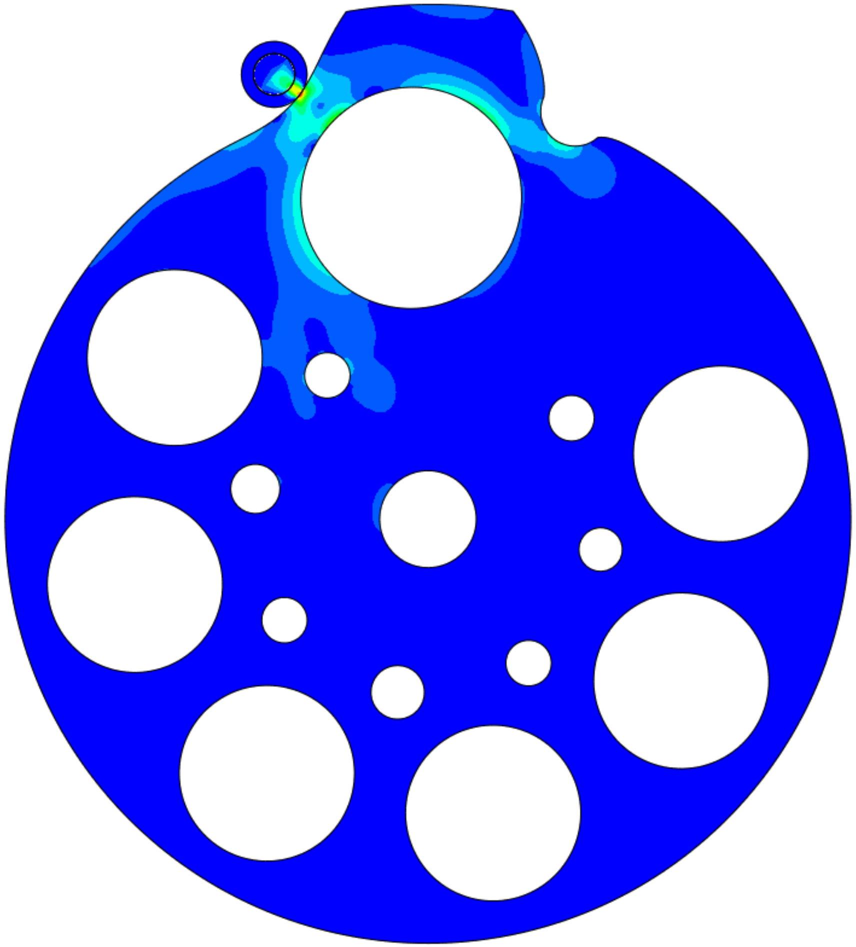


Conclusion: Production Cam Profile is Optimized for Roller Loads

Finite Element Model

Force Time History from ADAMS used as Input to a Finite Element Model

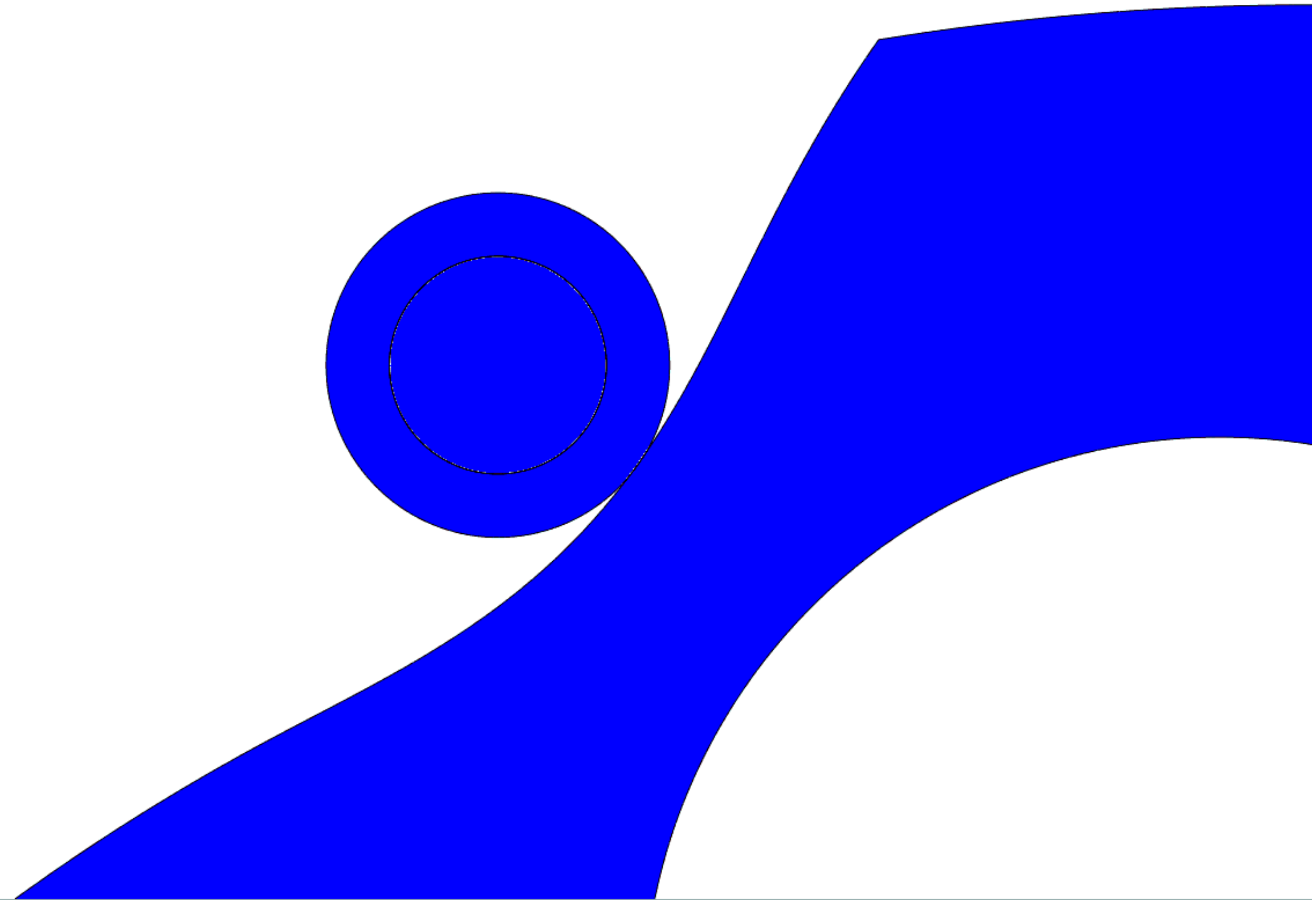
- Transient Dynamics
- Frictional Contact
- Material Plasticity



Snapshot of Stresses
During Impact

Finite Element Model – Animation

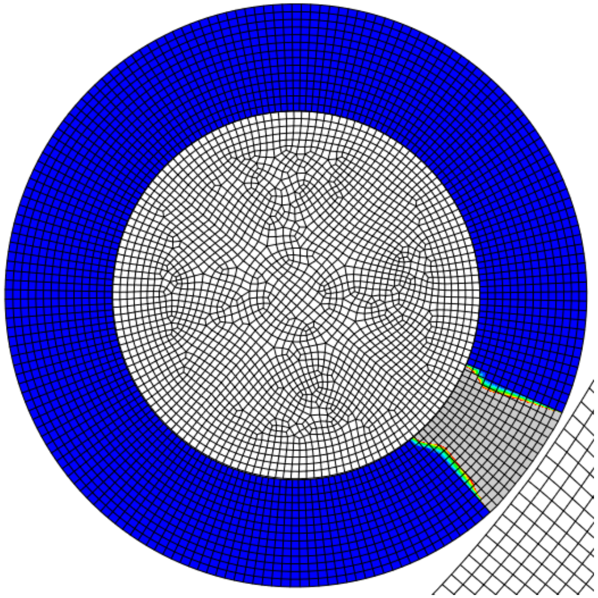
Animation of Stresses During Impact



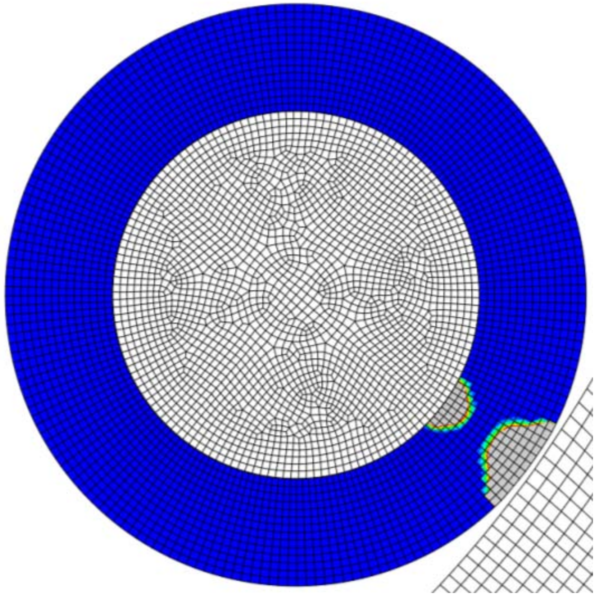
Roller Plasticity

Plots of Post-Impact Plastic Strains:

- Blue Indicates Zero Plastic Strain
- Results from Plane-Stress Models



Model of Early BMIII
Development Testing



Model of BMIII
With Production Material

Conclusions

Outcome:

1. **Ferguson Cam Tools and Processes Developed**
   a) Independently Create Cam Geometries
   b) Calculated and Corroborated Loads with Field Experience
   c) Developed Understanding of Mechanism Parameters that Drive Loads

2. **Investment in Developing These Tools Has More Than Paid for Itself**
   a) This was a Long and Difficult Analysis Process (12 Months)
      - 9 Months to Develop Tools to First Load Calculations
      - Then 8 Designs Investigated In 1 Month!
      - Simply Not Possible Without These Tools

   b) Drastically Cut Lead Time for New Cam Drawings
      (12 Months to 1 Month; Actual Cam Surface Creation Less Than 1 Day)
   c) Leveraging Cam Understanding into Entire Product Line

Questions?