Materials Database Development for Ballistic Impact Modeling

J. Michael Pereira
NASA Glenn Research Center

A set of experimental data is being generated under the Fundamental Aeronautics Program Supersonics project to help create and validate accurate computational impact models of jet engine impact events. The data generated will include material property data generated at a range of different strain rates, from $1x10^{-4}$ sec-1 to $5x10^{4}$ sec-1, over a range of temperatures. In addition, carefully instrumented ballistic impact tests will be conducted on flat plates and curved structures to provide material and structural response information to help validate the computational models. The material property data and the ballistic impact data will be generated using materials from the same lot, as far as possible.

It was found in preliminary testing that the surface finish of test specimens has an effect on measured high strain rate tension response of AL2024. Both the maximum stress and maximum elongation are greater on specimens with a smoother finish. This report gives an overview of the testing that is being conducted and presents results of preliminary testing of the surface finish study.

Materials Database Development for Ballistic Impact Modeling

J. Michael Pereira
NASA Glenn Research Center
FAP Annual Meeting
Oct. 31, 2007

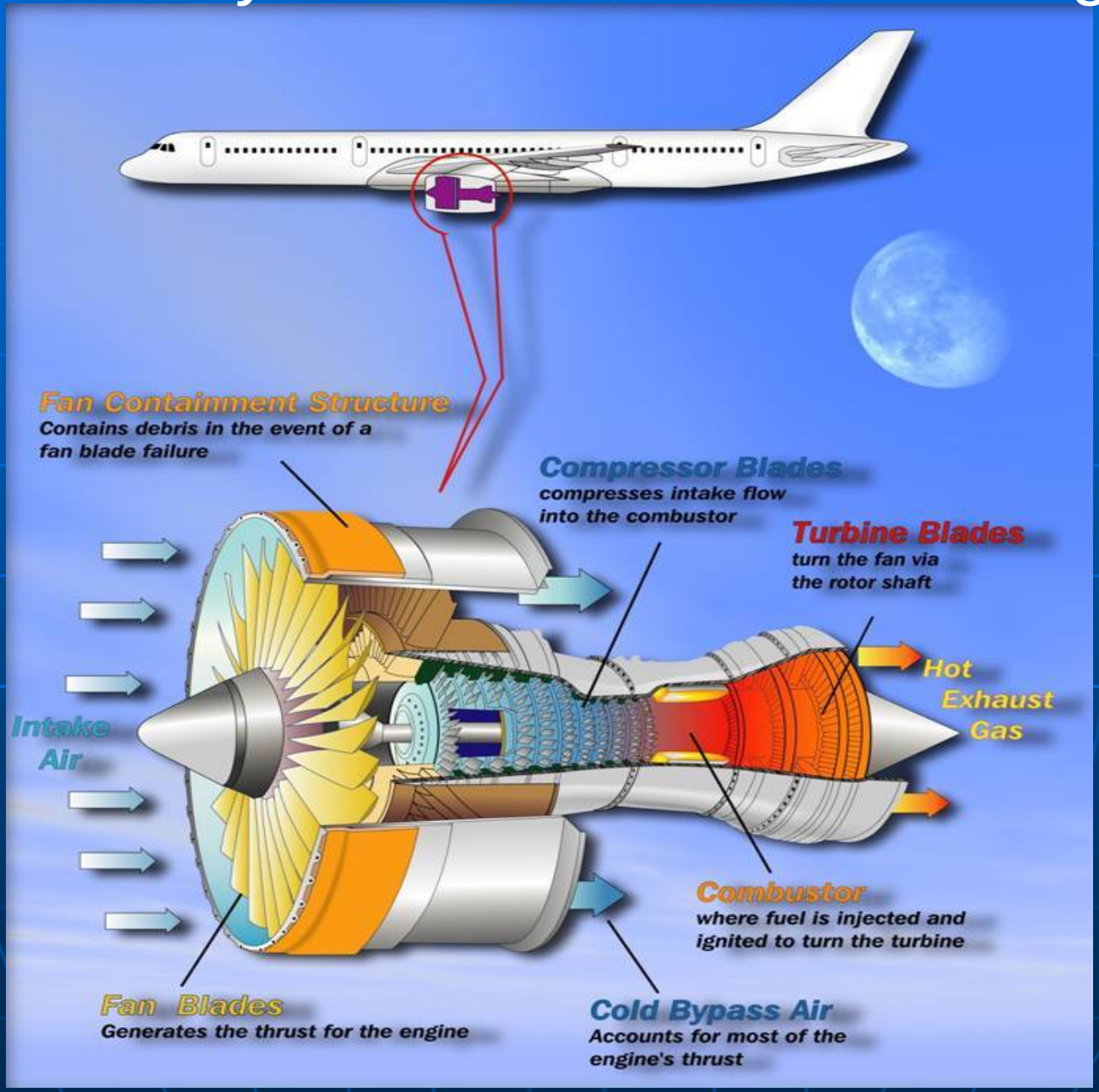
Issues

1. Lack of consistency in material modeling practices
2. Lack of high quality set of data to develop and verify impact models
   - Data typically assembled from a number of different sources
   - Lack of quantitative measurements to evaluate model accuracy
   - Limited pedigree

Outline

- Overview of project
- Status of impact testing
- Status of material property testing
- Results of work done on the effects of specimen surface finish on material property measurements

Anatomy of an Aircraft Turbine Engine



Objectives

- Develop a set of data to help improve and validate computational impact models
  - Material property data
  - Ballistic impact test results
- Develop improved methods for modeling impact problems

Initial Materials

- Ti-6Al-4V
  - 0.090 in
  - 0.140 in
  - 0.25 in
- Al 2024-T3/T351
  - 0.125 in (T3)
  - 0.25 in (T351)
  - 0.50 in (T351)

Database Contents

- Material Property Data
  - Shear, compression and tension
  - Different strain rates
  - Different temperatures
- Ballistic Impact Test Data
  - Flat plate tests
  - Subcomponent tests
- Damage Characterization

Material Property Measurements

- Tension, shear, and compression tests will be done at various strain rates ranging from 10^{-4} to $5x10^{3}$ s^{-1}. Tests at various elevated temperatures will be done at one of the strain rates.
- Tests at strain rates from 10^{-4} to 2 s^{-1} will be done using a hydraulic Instron machine. Tests at strain rates from 300 to 5000 s^{-1} will be done using the tension, compression, and torsion split Hopkinson bar techniques.

Ballistic Impact Tests

- Flat panel tests
- Subcomponent tests

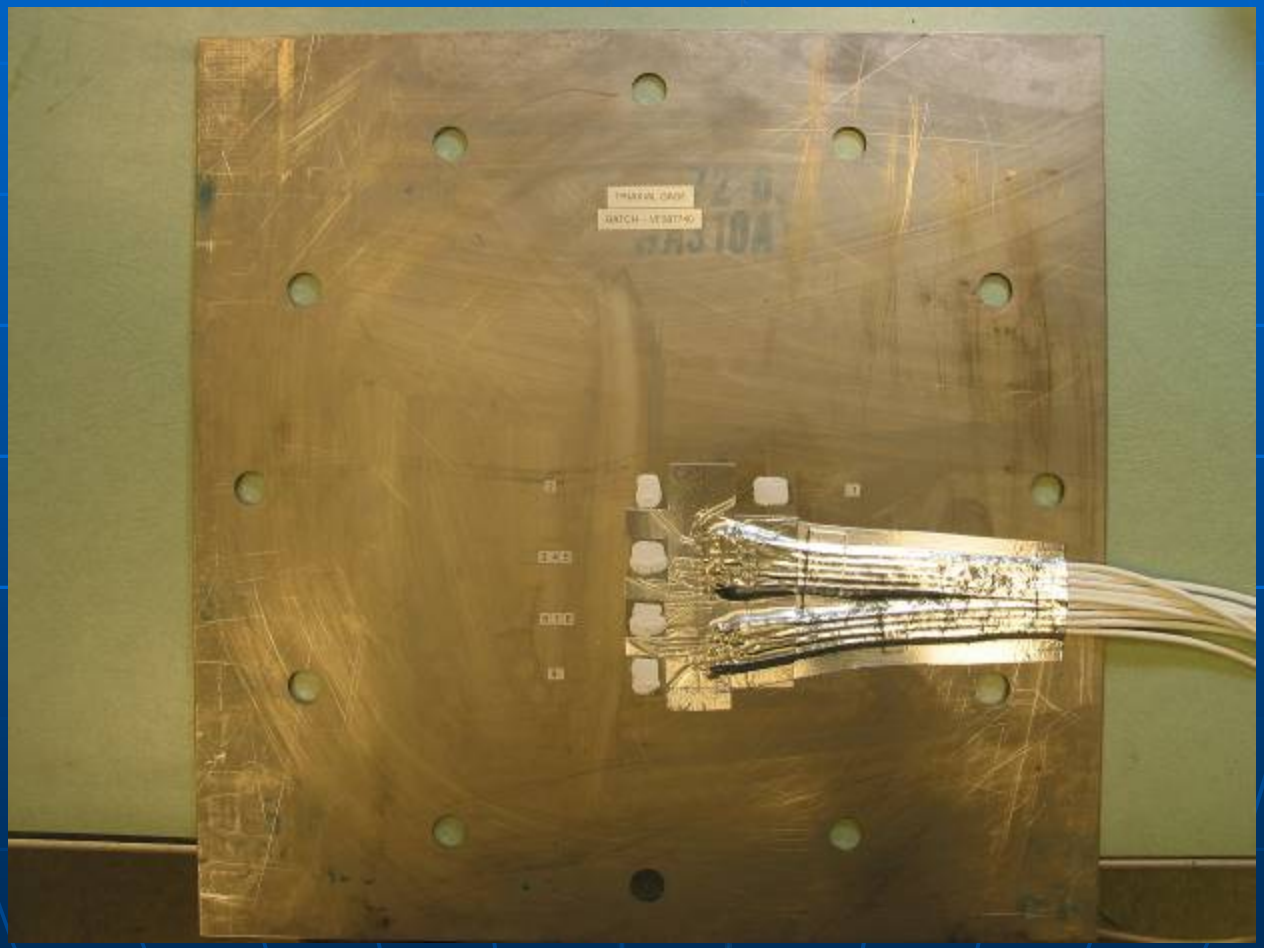
Flat Panel Tests

- Design projectile so that the penetration velocity is between 600-900 ft/sec
- 15” square panels rigidly clamped on four sides with a 10” round aperture
- Cylindrical projectile with a large radius nose, normal impact

Impact Gun

Test Fixture

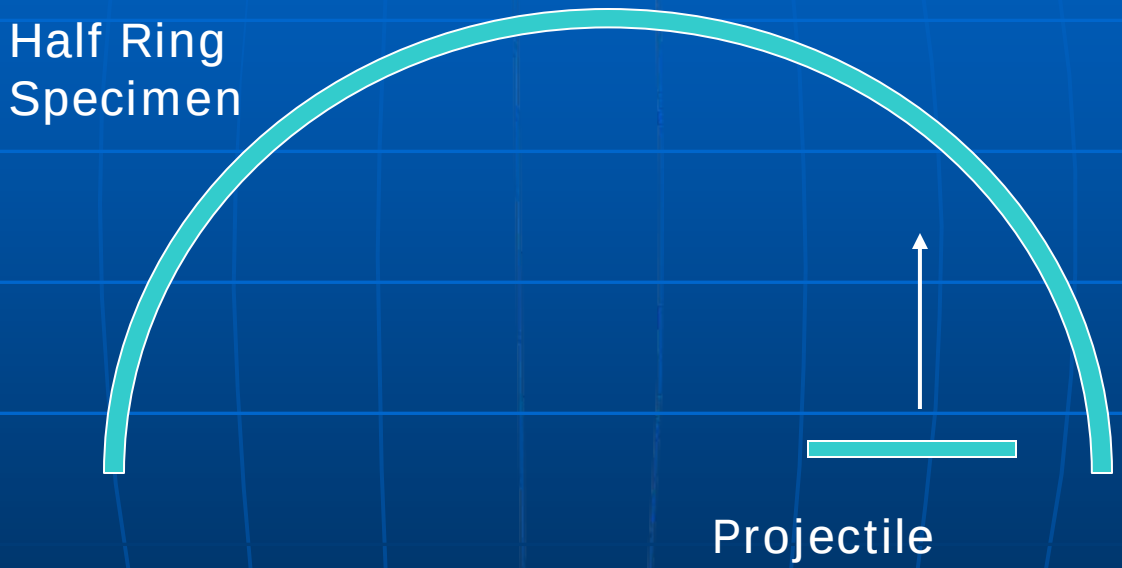
Instrumented plates



Test Fixture

Projectiles

Subcomponent specimen



Large gas gun

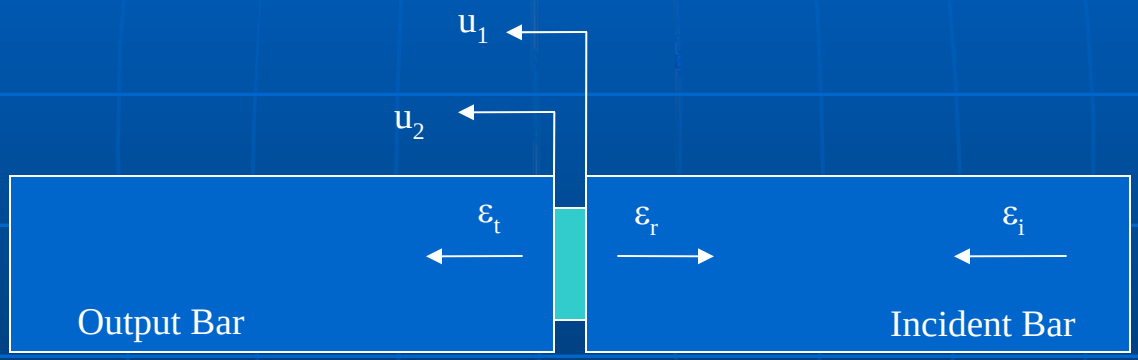
Instrumentation

- Point strain on backside (strain gages)
- Impact velocity
- Exit velocity
- Projectile orientation
- Full field displacement/strain (stereo photo instrumentation)

Test Program Status

- Flat plates have been instrumented
- Test fixtures have been fabricated
- Material property test specimens have been designed and testing has begun
- Surface finish study has been completed

Split Hopkinson Bar Apparatus



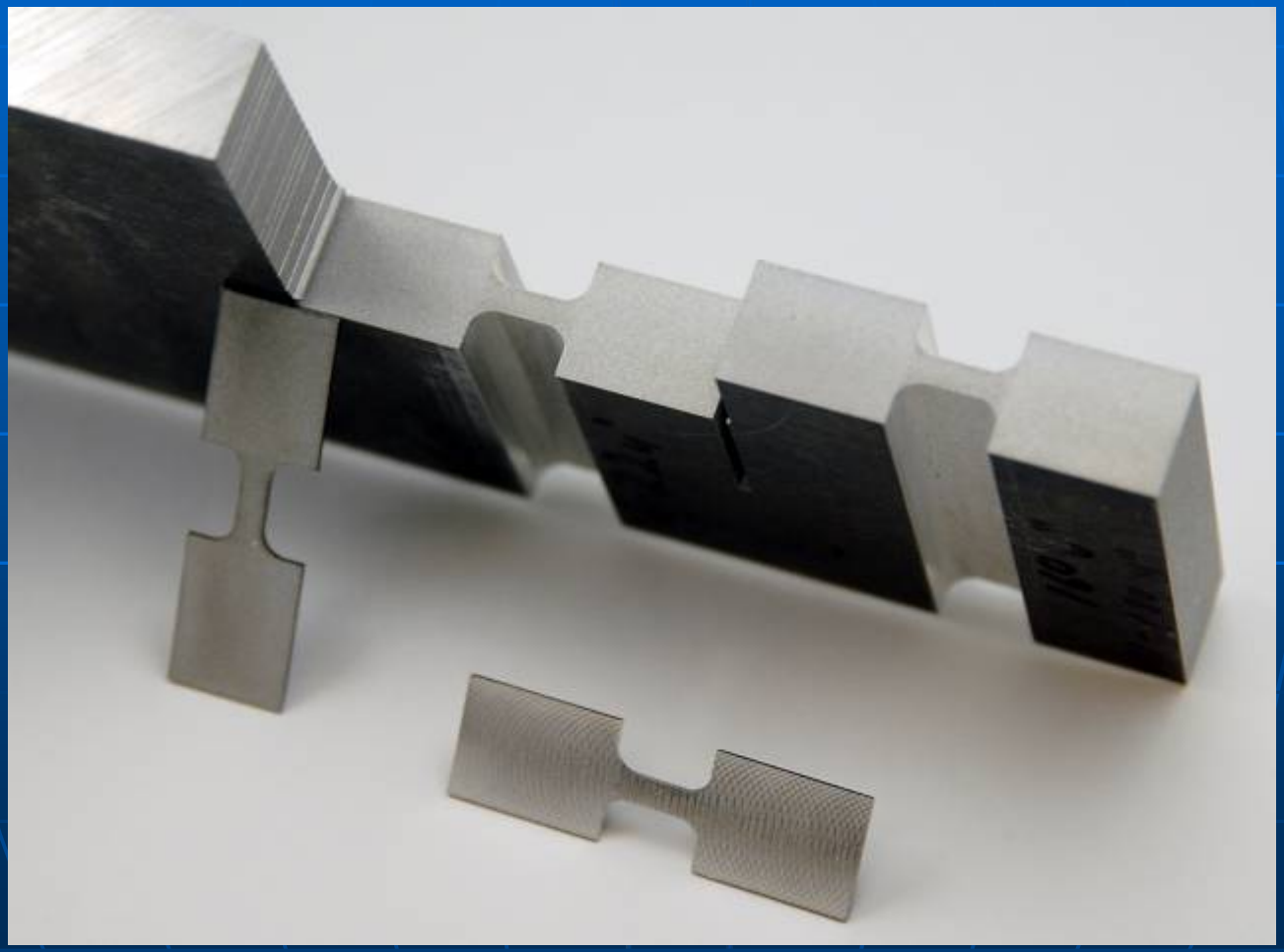
Effects of Surface Finish on High Strain Rate Material Property Measurements

- No standards exist for design of Split Hopkinson Bar test specimens
- Preliminary Study initiated to determine the effects of tension specimen surface finish

Number of Repeats per Condition

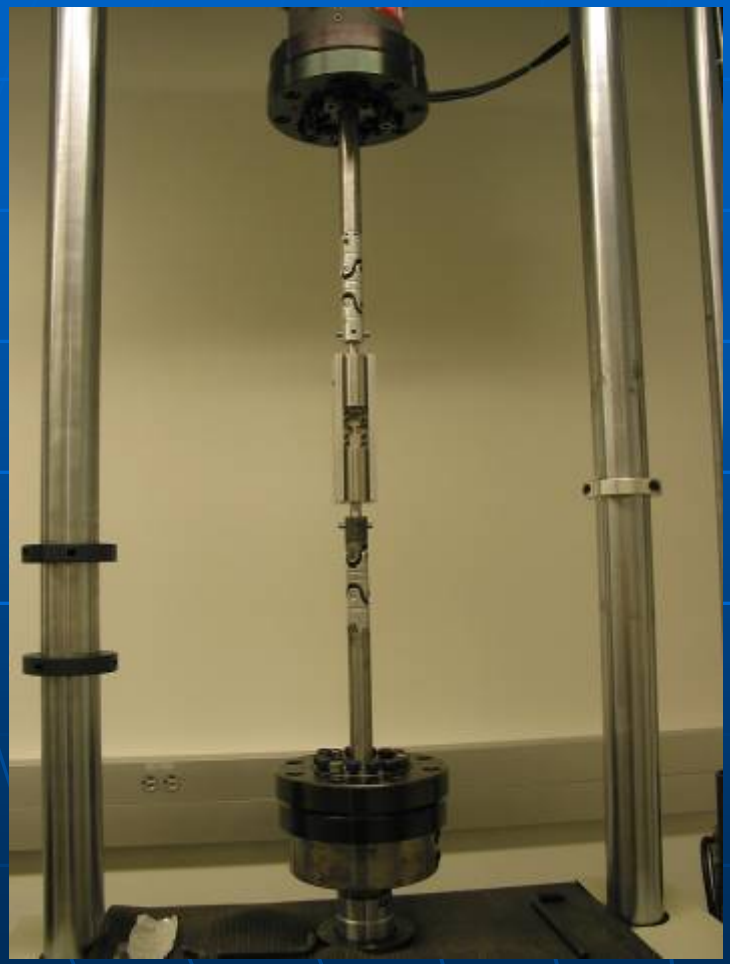
	Quasistatic (1/sec)	High Strain Rate (1000/sec)
EDM Specimen Unbroken Edges	3	3
Machined Specimen Ra 32 or better Unbroken Edges	3	3
Machined Specimen Ra 32 or better Edges Broken	3	3
Machined Specimen Ra 63 or worse Unbroken Edges	3	3

Tension Specimens



Tension Split Hopkinson Bar

Quasistatic Apparatus



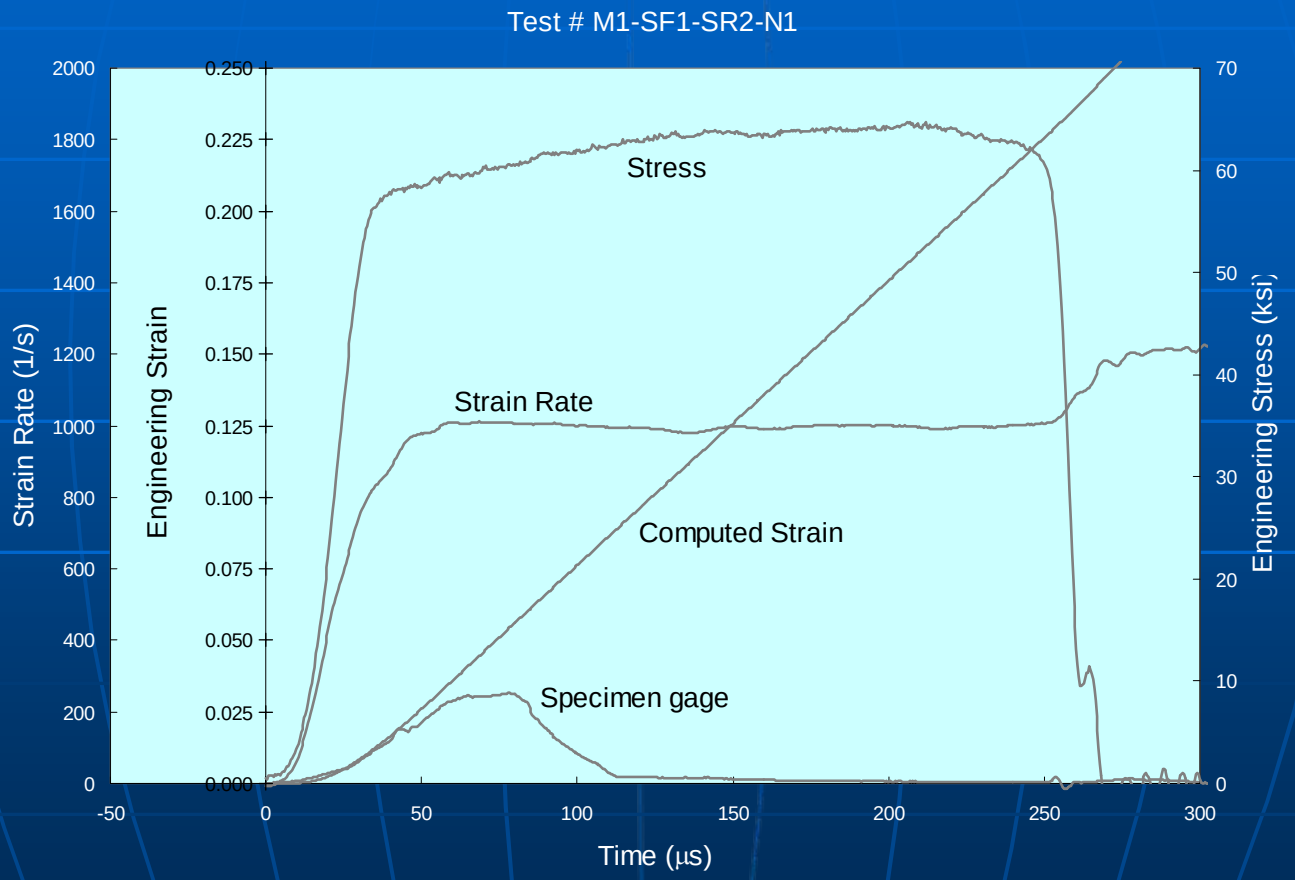
SHB Tension Specimen

SHB Specimen – Post Test

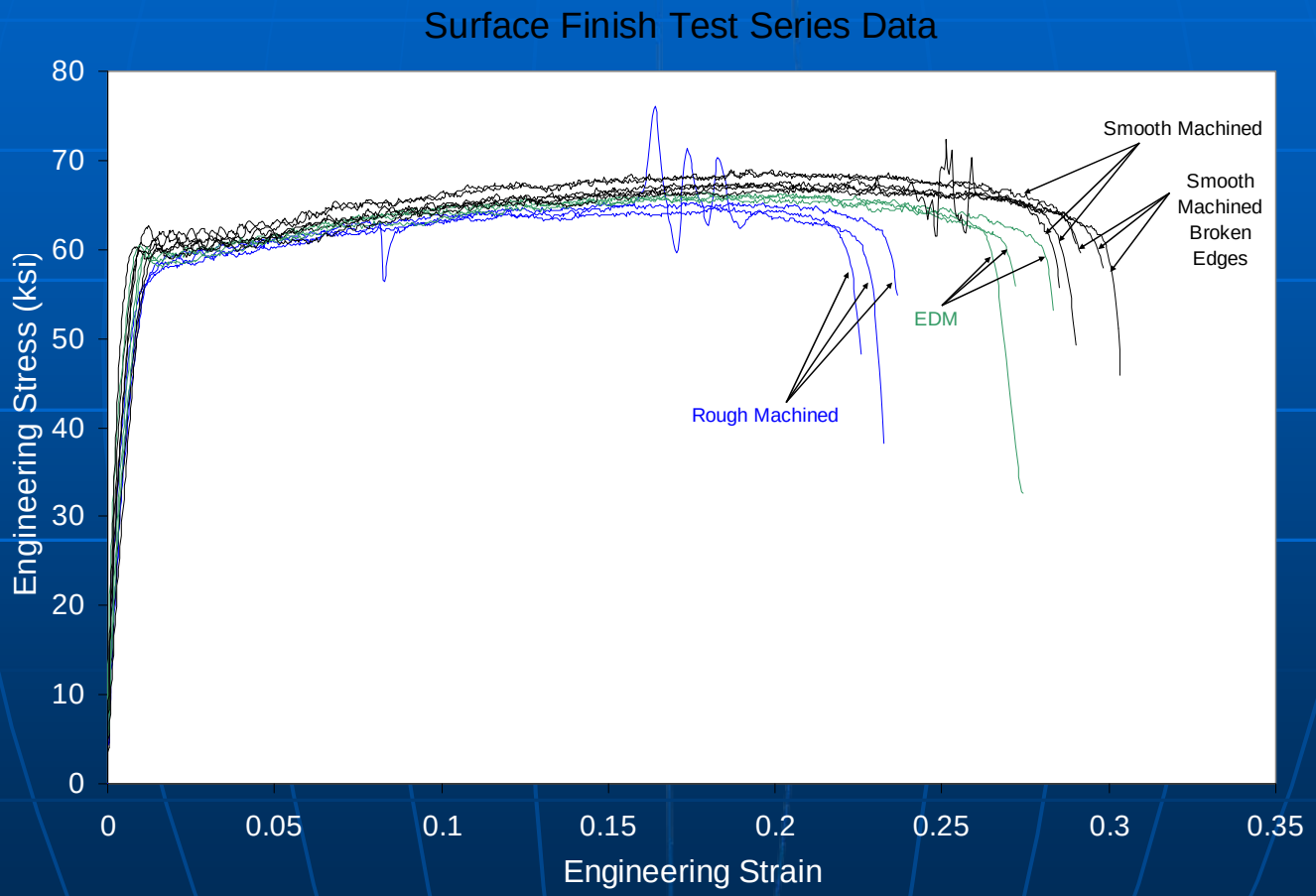
Surface Roughness Measurements

Specimen	Parallel to Specimen Axis (Ra)	Perpendicular to Specimen Axis (Ra)	Gage Section Edge (Ra)
EDM	107-118	107-118	15
Rough Machined	125-170	84-124	111-180
Smooth Machined	13-22	8-20	16-22

High Strain Rate Results



Surface Finish Study Results 1000 in/in/sec



Conclusions

- Increase in elongation in smooth specimens
- Small increase in strength in smooth specimens
- EDM specimens show slight reduction in strength and elongation
- All testing should be done with smooth machined specimens