

The Gear Research Institute
www.gearresearch.org

presented to

AGMA Strategic Resources Network
Regional Meeting
GE Transportation Headquarters, Erie, PA
June 9, 2010
by
Dr. Suren Rao



Gear Research Institute

www.gearresearch.org

Mission

The Gear Research Institute leads and performs research, development and testing to support the gear industry. It will also promote education and technology transfer in support of the same industry sector.

Institute Facts

- **Not for profit corporation registered in the state of Illinois**
- **Managed by a tripartite Board of Trustees**
 - **Three members nominated by the ASME**
 - **Three members nominated by the AGMA**
 - **Three members elected by members of the GRI**

GRI Historical Background

- Started in Naperville, IL , 1982
- Held First International Conference on ADI, 1984
- Affiliated with the ASME, 1985
- Held Second International Conference on ADI, 1986
- Formed the Aerospace Bloc for Cooperative, Pre-competitive Research 1988-present
- Formed Worm Gear Bloc for 1988-1995
- Formed the Vehicle/Industry Bloc, 1989-2000
- Moved to Lisle,IL 1989
- Affiliated with AGMA, 1991
- Formed the Induction Hardening Group, 1993-1998
- Relocated to Northwestern University, 1994
- Held First International Conference on Induction Hardened Gears, 1995
- Relocated activities to the Drivetrain Technology Center (DTC) at Penn State's Applied Research Laboratory, 1996



Drivetrain Technology Center

Mission

Operate a technology resource that supports the drive train industry to address the technology challenges in mechanical power transmission systems, while educating and training the next generation of scientists, engineers and technologists.

Center Facts

- Initiated by Navy ManTech in 1992 at the Applied Research Laboratory (ARL)
- Currently sponsored by Army, GRI and industry



- U.S. Navy established the Applied Research Laboratory at Penn State in 1945
 - Eric Walker, first Director (1945-51) and Penn State President (1956-70)
 - Intercollege Graduate Degree Program in Acoustics established in 1965



- In 1996, Navy reaffirmed its strategic relationship and commitment by designating ARL as a University Affiliated Research Center (UARC)



- ARL faculty and staff provide technical leadership in the DoD for our areas of expertise. Additionally, we educate the next generation of scientists and engineers
- ARL is the largest research unit within Penn State with more than 1,200 faculty and staff. Primary organizational focus is on research, technology development and technology implementation



GR/DTC

Objective

Increase performance (increase power density, reduce vibration/noise) and reduce costs of mechanical power transmission systems and components

- **Manufacturing**
 - Develop new processes for the manufacturing of drive system components (gears, bearings)
 - Characterize/optimize existing processes to maximize durability and performance of gears
- **Materials**
 - Introduce advanced steels for gear applications
- **Metrology**
 - Utilize established transmission vibration/noise models to predict and enhance gear/transmission performance and health



Manufacturing-Projects

- **High Strength P/M Gears for Vehicle Transmissions-Army**
- **Development of near-net forging for increased bending strength-Boeing/Army**
- **Evaluation of tooth bending strength due to the “Intensive Quench” process-DCT**



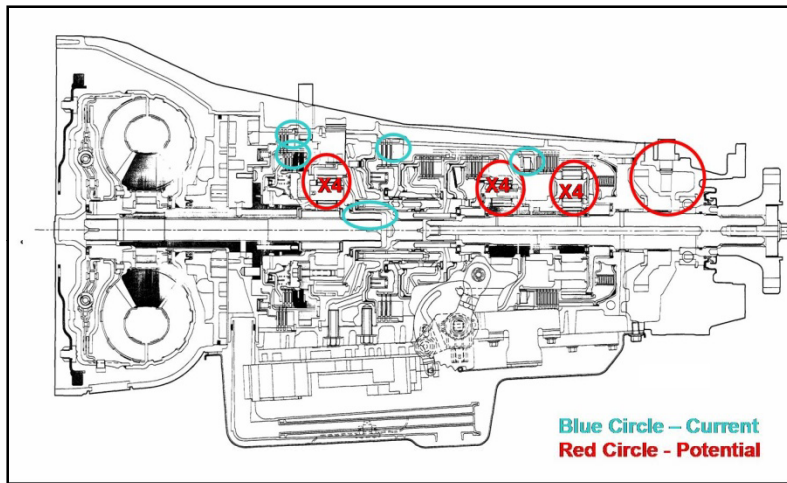
High Strength, P/M Gears for Vehicle Transmissions

Sponsor: Army/TARDEC/NAC

Prime: Applied Research Laboratory/Penn State (PSU)

Subs: Keystone Powder Metal (KPM), Kinefac Corporation

Rationale for Processing P/M Gears



P/M parts typically cost less than conventionally processed parts in high-volume production (between 40-60%)

Advanced P/M compositions and processing techniques have substantially improved bending strength, almost equivalent to wrought steels

However, surface fatigue and wear resistance of P/M gears needs to be improved to be comparable to wrought steels

Ausform finishing of P/M gears has the potential to substantially improve the surface fatigue and wear resistance of P/M gears



What is Ausforming?

Process

- Modified steel heat treatment process
- Plastic deformation of metastable austenite

Benefits

- 30-50% increase in strength
- Over 60% reduction in manufacturing time due to elimination of operations
- Cost-effective integrated in-line manufacturing operation

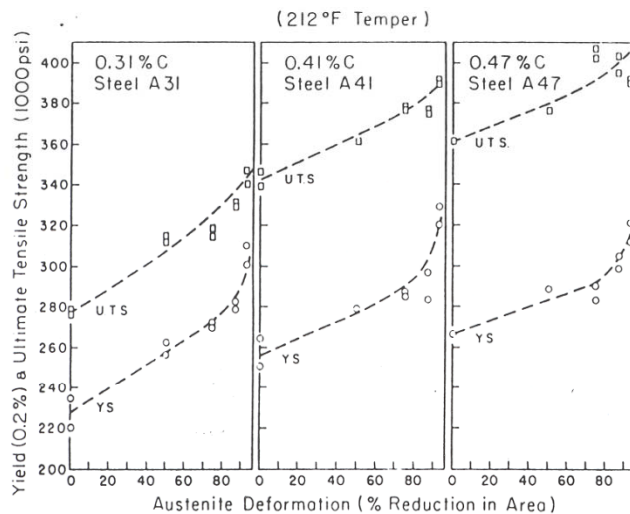
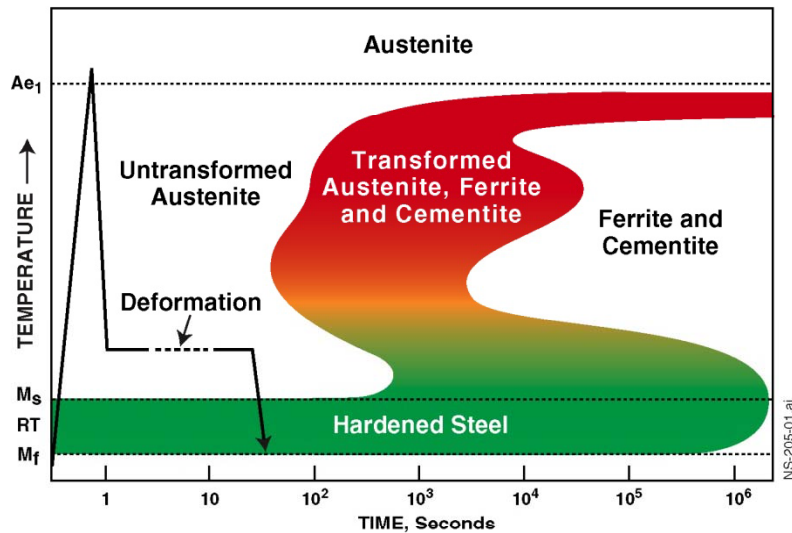
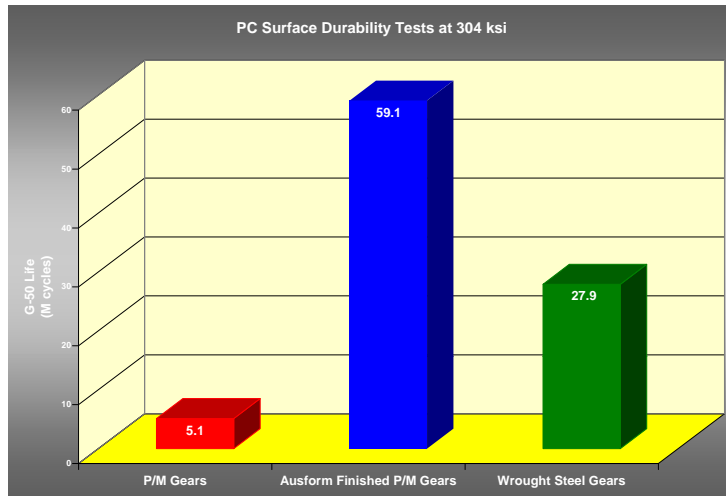
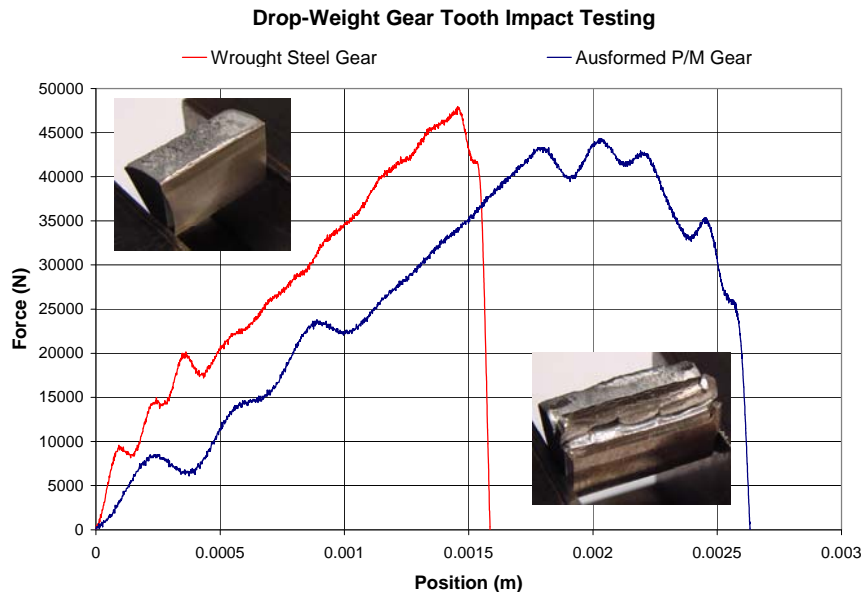


Fig. 2—Yield and Ultimate Tensile Strength as Influenced by Deformation of Metastable Austenite. These data refer to air melted steels tempered at 212 °F.



Accomplishments

- Demonstrated G_{50} pitting fatigue life, scoring resistance and impact resistance of ausform finished P/M gears is higher than current wrought steel gears
- Demonstrated bending fatigue strength of ausform finished P/M gears is equivalent to wrought steel gears
- Established 40% cost savings with ausform finished P/M automotive pinions over conventionally manufactured pinions of the same quality
- Designed and procured a production, P/M gear ausform finishing machine to establish statistical process capability parameters and conduct application studies for industry



Materials-Projects

- **Design allowables for AMS 6308 steels-Aerospace Bloc**
- **Comparative durability and strength of advanced gear steels P675, CSS42L, Ferrium C61 and C64-Aerospace Bloc**
- **Evaluation of high performance gear materials and coatings-Timken**
- **Evaluation of gear steels for wind turbine applications**

Gear Research Institute

#A-1020 Aerospace Bloc

**(Avio Group, Boeing, Curtiss Wright, General Electric, Honeywell,
Latrobe Steel, Pratt & Whitney (E. Hartford & Canada), Rolls Royce,
REM, Sikorsky)**

**All data, reports, meeting minutes and presentations are
available on-line to Bloc members**

Develop Design Allowable Data for AMS 6308 Steel

Objective

Develop design allowable bending strength, surface durability and scoring resistance data for AMS 6308.

Tests conducted using the power re-circulating (PC) approach.

Status

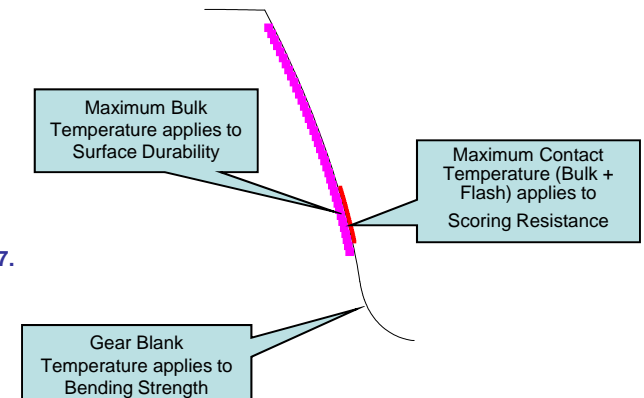
Project completed 2008; Final Report and fatigue data available on-line for Bloc members

AMS 6308 Follow-On

Analysis of collected data indicated statistical insufficiency for developing design data. Three steps are being implemented to achieve statistical sufficiency

- Conduct more PC bending tests
- Conduct more PC surface durability tests
- Conduct further tests with gear blank and tooth bulk temperature at 400⁰ F (1)

1. Rao S., McPherson D. "Gear Tooth Temperature Measurements", *Gear Solutions*, August 2009, vol. 7, no. 77.



Comparative durability and strength of advanced gear steels P675, CSS42L, Ferrium C61 and C64

Objective

Develop comparative surface durability and tooth bending strength properties of 4 advanced gear steels

- Rotating/sliding contact fatigue tests (RCF)
- Single tooth bending fatigue tests (STBF)

Status

- RCF tests complete on P675 and CSS42L
- P675 and CSS42L gears for STBF in process
- Ferrium C61 and C64 materials being procured

Single-Client Projects

- **Evaluation of high performance gear materials and coatings-Timken**
- **Evaluation of gear steels for wind turbine applications**
- **Evaluation of tooth bending strength due to the “Intensive Quench” process-DCT**
- **Diagnosis of gear vibrations/noise due to manufacturing errors-AGMA Foundation**



Metrology-Capability

Analytical models to predict vibration and noise in a gear box, based on load, tooth geometry and manufacturing errors

Recent Projects

- Design methodology for minimum vibration and noise gears-CRI
- Gear Noise Prediction from Measured Surfaces-USCAR

PENNSSTATE



ARL



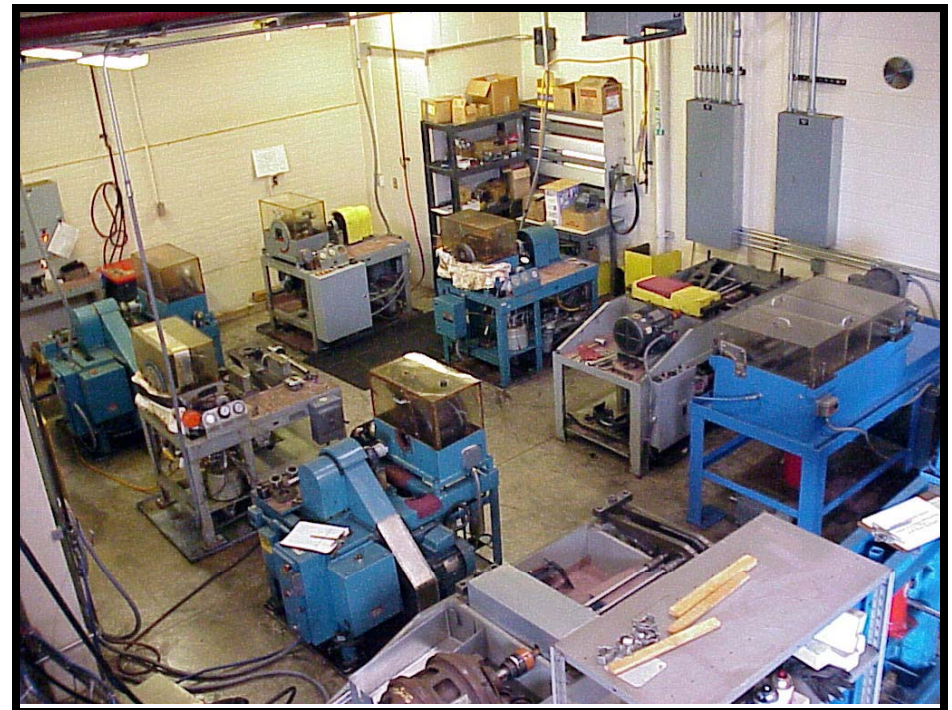
Facilities

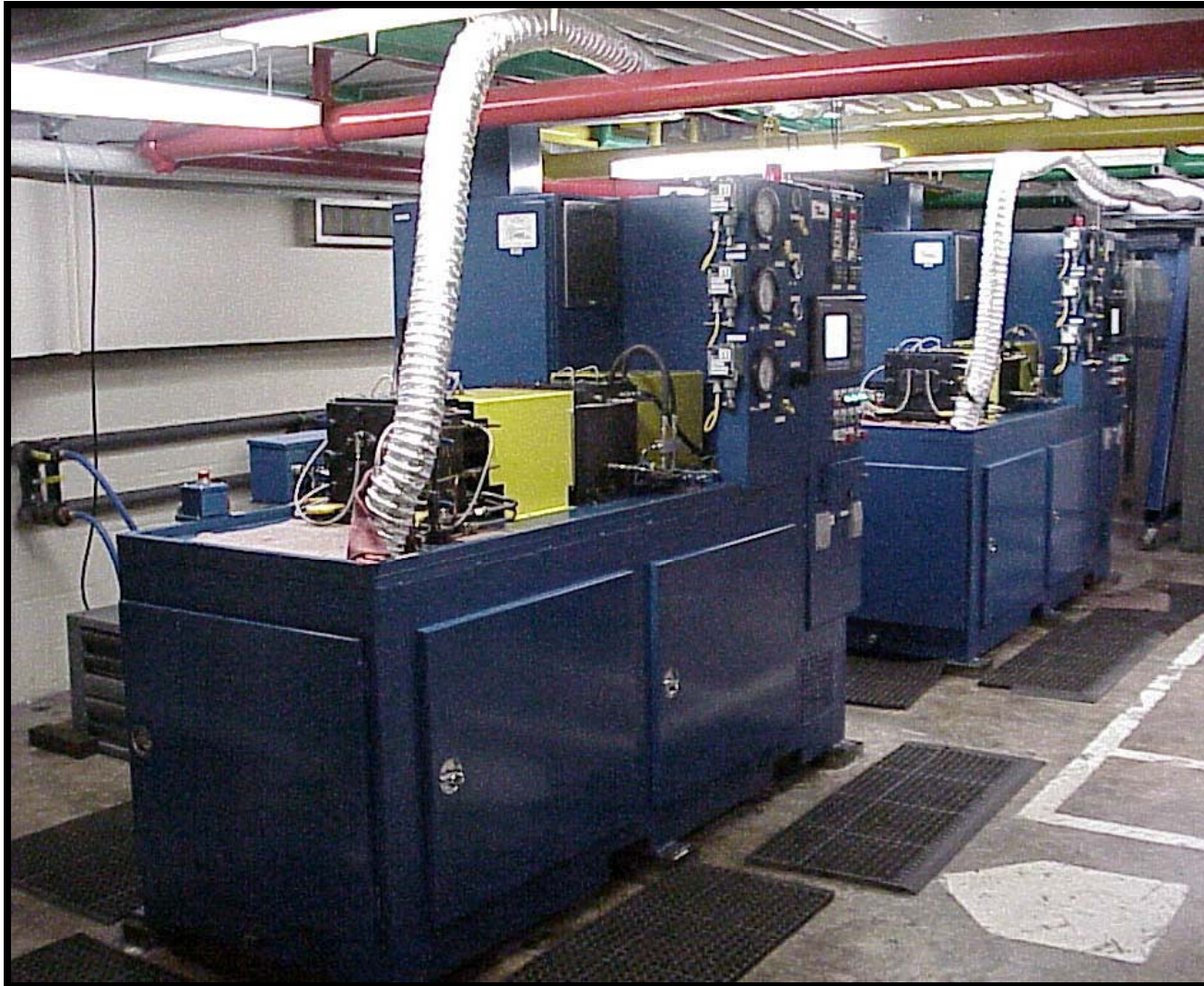
Gear Testing Facilities

Single Tooth Bending Fatigue Stands



Rotating Contact Fatigue Testers

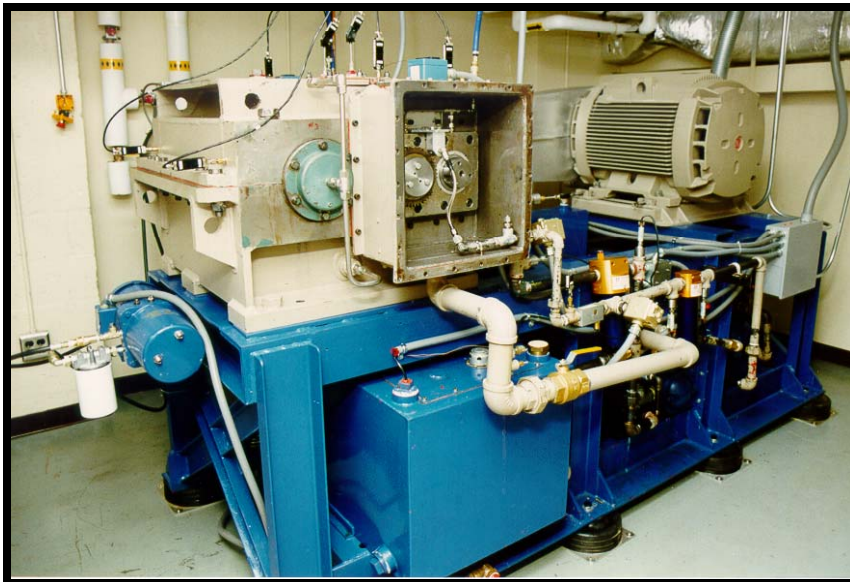




Power Circulating Gear Tester

Gear Inspection and Testing Facilities

Power Circulating Gear Tester



Gear Inspection Machine





Grants for student support

- Corporate Membership in GRI-\$600/year (supports undergrads.)
 - Receive newsletters, nominate and vote for Board, attend Annual meeting
 - Join to have access to valuable topical events
 - Join to have access to cost effective, authoritative testing
 - Join to reduce internal development costs
 - Join to expand you network
 - Join to guide future research efforts
 - Join to support education in gear technology
- Undergraduate internships
 - Summer \$8,500
 - Semester (half time) \$5,000
- Graduate Assistantships
 - MS (typically three semester plus a summer) \$70,000
 - Ph.D (typically 6 semesters plus two summers) \$160,000
 - Additional funds may be necessary if research project requires hardware

PENNSSTATE



ARL



Questions