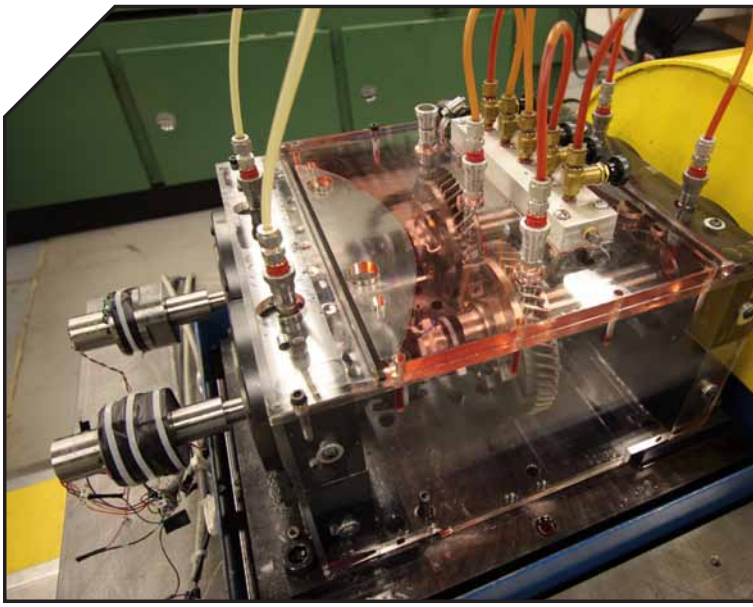
The Gear and Power Transmission Research Laboratory: Where Innovation Thrives

Jack McGuinn, Senior Editor



When, in 1980, OSU professor Donald R. Houser created the Gear and Power Transmission Research Laboratory — then known as the Gear Dynamics and Gear and Power Transmission Laboratory (GearLab) — he did so with the seed money provided by just three companies. Thirty-three years out, the lab has continued to grow, impress and—most importantly—succeed; it now boasts a roster of some 50 sponsoring companies and government agencies.

In 2003 GearLab merged with a research group headed up by Professor Ahmet Kahraman (see interview to follow), who was then at the University of Toledo's Center for Gear Research. The partnering led to a dramatic expansion of GearLab capabilities and facilities, in turn leading to explorations into the farther reaches of gear and power transmission research. Kahraman in 2006 assumed directorship of the center, as Houser retired from active teaching.

All along, the GearLab has been on a mission, a mission dedicated to aiding its participating (sponsoring) industries and government agencies by "enhancing gear and power transmission technology through fundamental and applied research and transfer research results; providing graduate and undergraduate students with applied educational and research opportunities in gear- and power transmission-related disciplines; and keeping sponsors updated on the latest gear and transmission technologies."

The referenced "sponsors" are members of the GearLab Consortium. The group includes some of the biggest and most influential companies and agencies in the country. Among Consortium membership benefits:

- Access to research findings with good leverage of investment
- Licenses to state-of-the-art computer software for gear design and analysis
- Access to experimental databases of GearLab
- Access to past GearLab research in the form of papers, reports and theses
- Limited consulting services, free of charge
- And what is required of would-be Consortium members?
- $12,000 per year for companies with more than 250 employees; one-time initiation fee of $4,000 for new members
- $4,000 per year for companies with fewer than 250 employees; one-time initiation fee of $1,000 for new members

It is a perfect "win-win" for both the lab and the companies and government agencies that support it—true American capitalism at work. On one hand, interested — and paying — parties are served by some of the best engineering minds and most sophisticated testing equipment in the world, as GearLab personnel are charged with researching, say, a potentially major application or material breakthrough, etc. On the other, we, as a nation — along with the gear and its ancillary industries (and their stockholders) — benefit greatly from the work being done there. And one more invaluable benefit: engineers — aspiring or veteran — are able to work their wonders confident in the knowledge that they are set up for success—not failure. Example: since its inception, research dollars at GearLab at have exceeded $15 million.

A sampling of previous and ongoing Consortium-funded projects include:

- An experimental and theoretical investigation of modulation sidebands of planetary gear trains
- A model to predict overall transmission error of a planetary gear set
- Development of a load distribution model for spiral bevel and hypoid gears
- Development of a straight bevel gear load distribution model
- A model to predict overall transmission error of a planetary gear set

Some Consortium member companies: Gleason Corp.; Honeywell; Hyundai; Hyundai Heavy Industries; ITAMCO; John Deere; Rexnord; Meritor; Kawasaki Machine Industry; Pratt & Whitney; Moog; and Reishauer.

And government agencies/cabinet departments: Department of Energy (DOE), the Army Research Laboratory, and the National Renewable Energy Laboratory (NREL).

Perhaps most important of all is the fact that, according to the Gear and Power Transmission Research Laboratory's Website (*gearlab.org*), over 150 Masters and Ph.D. students have been supported and mentored by the GearLab, most of whom are now helping to fill those critical positions at gear and power transmission companies that often go unfilled when vacated by their retiring predecessors. And the GearLab is where two influential industrial short courses on gear noise — now considered industry-standard chapter-and-verse — were developed and offered to the industry by Drs. Houser and Rajendra Singh

—"educating more than 1,350 engineers from over 320 companies on the subject matter."

The GearLab's state-of-the-art facilities in the Scott Laboratory (since the 2006 renovation) include the Gleason Gear and Power Transmission Laboratory, bequeathed by the Gleason Family Foundation. The facility consists of six high-bay rooms and 4,000 square feet of laboratory space with built-in facilities such as isolated test beds and two computational research laboratories that house the research team. The test facilities are arranged in three laboratories, dedicated to experimental investigation of different aspects of gearing.

There is the ***Gear Dynamics Research Laboratory,*** which houses a number of state-of-the-art test set-ups and machines to investigate the behavior of gear pairs and gear systems under dynamic operating conditions. It includes the Gear Dynamics test machine designed to measure transmission error, vibrations and root strains of spur and helical gears with or without shaft misalignments. Both encoder- and accelerometer-based transmission error measurement systems are incorporated with this test machine. Another valuable test set-up is a planetary test gear machine to measure planet load sharing, efficiency and dynamic behavior of planetary gear sets under loaded conditions. Other test set-ups in this lab include a low-speed load dynamometer currently being used for planetary gear set and hypoid transmission error measurements, as well as a full-scale transmission dynamometer suitable for loaded dynamic tests of gearboxes, transmissions and spin tests of axles.

The Gear Efficiency and Fatigue Research Laboratory also features a number of test machines, designed specifically to evaluate the efficiency and durability aspects of gears, gear materials and lubricants: Two twin-disk test machines for contact fatigue, scoring and traction measurements; an efficiency test machine with helical gear efficiency fixtures that is

Home to some of the most sophisticated gear testing and monitoring equipment on the planet, the OSU Gear and Power Transmission Research Laboratory boasts a gear dynamics test machine designed to measure transmission error, vibrations and root strains of spur and helical gears—with or without shaft misalignments. Also on the premises are three standard FZG gear durability test machines (next page) for performing pitting, tooth bending fatigue and scoring tests.

The Consortium, comprised of sponsoring companies and government agencies, is what keeps the lights on at the Gear and Power Transmission Research Laboratory. Consortium members' need for invaluable research and development—and their willingness and ability to pay for it—are the drivers for the valuable work done there by lab personnel (all photos courtesy Gear and Power Transmission Research Laboratory).

designed to evaluate loaded and unloaded power losses of gear pairs under high-speed (up to 10,000 rpm) and high-load conditions (up to 700 Nm); three standard FZG gear durability test machines for performing pitting, tooth bending fatigue and scoring tests; and an MTS load frame fixture to perform single-tooth bending fatigue tests.

The third facility, the ***Gear Metrology Research Laboratory,*** supports the experiments occurring in the other two laboratories by providing systems for the measurement of surface roughness and tooth profiles, and imaging the test surfaces. A Gleason-Goulder single-flank, unloaded transmission error tester, a Gleason M&M gear CMM, a Taylor Hobson Tally-Surf surface roughness profiler and miscellaneous digital microscopes and data collection and analysis instrumentation are also available in this lab.

Add to all this a priceless cache of research-specific technical papers produced in-house over the years and typically presented at VDI- and ASME-sponsored conferences.

Bottom line — after the money has been spent, the checks have been cashed and the work completed—virtually every project the Gear and Power Transmission Research Laboratory takes on is done so with the following goals firmly in its sights:

- Increase power density
- Improve quality
- Reduce noise and vibration
- Improve efficiency and lubrication
- Reduce cost of power transmission and gear systems

It is, after all, what gear systems designers strive for every day. And what is accomplished at the Gear and Power Transmission Research Laboratory — the GearLab — on a daily basis.

(*For more on the Gear and Power Transmission Research Laboratory, please see accompanying Q&A with lab director* Ahmet Kahraman.)

For more information:

Ahmet Kahraman, professor and director
Gear and Power Transmission Research Laboratory
DepartmeThe Ohio State University
201 W. 19th Avenue
Columbus, OH 43210
Phone: (614) 292-4678
Fax: (614) 292-3163
kahraman.1@osu.edu

A *Gear Technology* Interview with Ahmet Kahraman, Director, Gear and Power Transmission Research Laboratory

Jack McGuinn, Senior Editor

Gear Technology (GT). Can you tell us about the projects sponsored at the GearLab?

Dr. Ahmet Kahraman (AK). Projects sponsored by the OSU Gear Research Consortium cover a wide spectrum of gear topics, including gear design optimization; gear contact mechanics; gear system dynamics; gear tribology and lubrication; gear system efficiency; contact and bending fatigue; surface wear; and scuffing. At any given time, we will have 7–10 (masters and doctorate) students supported by the Consortium to perform such research projects. Research findings are presented to the Consortium members and implemented in our software packages that are licensed to the members.

GT. What are "individually sponsored projects," and how do they work?

AK. These are the projects funded by a single company, while on some occasions more than one company might partner up to fund a project. The sponsoring company may or may not be a member of the Gear Research Consortium. (The) sponsoring company funds the entire project exclusively. The results of these projects are kept confidential (i.e., they are not shared with the Consortium membership). A research contract agreement is signed between the company and the University to address all legal issues including non-disclosure, licensing as well as publications.

GT. Is your work split evenly between government and industry, or something else?

AK. We work with government entities such as the (Department of Energy, National Renewable Energy Laboratory and the Army Research Laboratory) on the Federal side, while more than 80 percent of our current funding is industrial in nature.

GT. In reviewing the GearLab site, it appears that a majority of your research is automotive-related. Accurate? If so, why the emphasis?

AK. About half of our research expenditures are automotive-related, while the rest is aerospace- and off-highway-related. Of 67 current consortium member companies, about 25 are automotive (OEM and 1st Tier suppliers), 10 are aerospace, 20 are off-highway and industrial gearbox companies, and the rest are from manufacturing, oil, consulting, software and recreational vehicle industries. As such, while we are involved with the automotive industry heavily, we cannot say our research is limited to automotive needs only. Our sponsor base is rather diverse, covering various industries.

GT. Assuming the GearLab is international in scope, are U.S. national security considerations ever a factor in working with a foreign entity?

AK. Yes, GearLab has an international focus and reach. Of 67 current members of the consortium, about one-third are non-U.S. companies from countries such as S. Korea, Japan, Germany, Italy, France, U.K., China, Turkey, Sweden, Canada and Mexico. Yet we are trained and set-up to perform research with ITAR (International Traffic in Arms Regulations) or export controls restrictions as well. We currently have several projects of this type and we have systems in place to fully comply with such requirements.

GT. What would you consider the GearLab's greatest achievement to date?

AK. While we are proud of the positive impact of our research on the gear and power transmission industries, and our contributions to the state-of-the-art in gearing, our greatest achievement within the last 30 years has to be our educational impact on the industry. We graduate about 10 students with (masters and doctorates) in gearing-related topics each year who are hired exclusively by power transmission companies. We have more than 175 GearLab alumni working in industry on gears and power transmissions; you can trace a many practicing gear engineers to GearLab. In addition, we also provide gear-related, industrial short courses. More than 1,500 engineers (have taken) our industrial courses over the years. As such, GearLab's greatest achievement has to be that it was able to educate gear technologists needed by the industry.

GT. Why aren't there more "GearLabs" in the U.S.?

AK. This might have many answers to it. The misguided perception that gears are a "mature" technology with limited research and science potential is perhaps one reason. U.S. universities will not hire new professors to work on gears, as this is not as high on their lists as other emerging areas, such as nano or bioengineering. Meanwhile powertrain industries have been dealing with real, tough and perennial issues that require immediate attention. (Another) reason might be that U.S. powertrain companies are not that enthusiastic about university research — perhaps due to their past experiences. There is still a perception that academic research is not applicable to practical problems. I would like to think that our projects in GearLab are examples to make a case that academic research can be done to investigate a science issue while at the same time solving a particular real-life problem of industry.

GT. What can be done to enlist more bright young people in mechanical and power transmission components engineering?

AK. Our strategy has been involving undergraduate students in gear research as early as possible. We engage sophomores and juniors actively and hire them as undergraduate research assistants early on. Once they become a part of GearLab and witness what we are all about, they typically stay with us through their graduate education.

Dr. Ahmet Kahraman is a Howard D. Winbigler professor of mechanical and aerospace engineering at The Ohio State University, and director of the Gleason Gear and Power Transmission Research Laboratory. He also directs the Pratt & Whitney Center of Excellence in Gearbox Technology. Kahraman was past chairman of the ASME Power Transmission and Gearing (PTG) Committee and the 2007 and 2009 ASME PTG Conferences. A former associate editor of the ASME Journal of Mechanical Design, he serves on the editorial boards of Journal of Sound and Vibration, Journal of Multi-Body Dynamics, and Mechanics-Based Design of Structures and Machines. Kahraman is an ASME fellow and member of STLE. He received his Ph.D. degree in mechanical engineering from Ohio State in 1990. His areas of research focus include gear system design and analysis; gear and transmission dynamics; gear lubrication and efficiency; gear and fatigue life prediction; and test methodologies.