

Aerospace Gearing Research— An update

Jack McGuinn, Senior Editor

As this is being written, an msnbc.com headline asks: “Defense Jobs—Recession-Resistant No More?” The story goes on to point out that defense/aerospace spending has always meant good, well-paying jobs for job shops and OEMs throughout the country. And like Chrysler’s recent nationwide shuttering of many of its locally owned dealer showrooms, the loss of defense contracts can have devastating effects on cities and towns, and attendant collateral damage. Indeed, national defense has—until this Great Recession—always proven to be recession-resistant. No more. These days, and for some time now, it is outer space that is attracting the dollars and generating contracts. Which, in a very limited sense, is good, except for the fact that deep space research—though admittedly sexier—occupies a very limited niche, where aerospace/defense boasts a much wider, guns-and-butter impact, affecting more jobs and companies. And yet, the work does in fact go on—at least in terms of invaluable research. With that in mind, we talked to three institutions long-respected in the gearing community—The Ohio State University Gear Dynamics and Gear and Power Transmission Laboratory (GearLab), the Gear Research Institute (GRI) and Applied Research Laboratory at The Pennsylvania State University and the Cleveland-based NASA Glenn Research Center, all with the idea of getting their take on the state of aerospace/defense research.

GearLab and Gear Research Institute at Head of the (Gear) Class

At Ohio State’s GearLab, founded



Sophisticated gear test rigs facilitate the often complex research projects at the GearLab (courtesy GearLab).

in 1980 by “Gear Professor Emeritus” Donald R. Houser, the roster of sponsoring companies and government agencies has grown steadily since its inception, now numbering approximately 50. In 2003, the GearLab partnered with a research group led by (current GearLab director) Professor Ahmet Kahraman, thus widening its breadth of research in gear and power transmission. Areas of GearLab’s research focus include:

- geometry, kinematics, design and analysis
- dynamics, vibrations, acoustics and noise control
- contact mechanics, load distribution models and FEA
- power losses and efficiency
- contact and bending fatigue
- metrology and test methodologies

At Penn State’s GRI, founded in 1982 and led by managing director Dr.

Suren Rao, the areas of focus differ, but are just as valuable:

- high-hot hardness gear steels
- utilization of Boron-toughened steels
- technology surveys
- durability testing of gears
- effect of lubricants on durability
- heat treat distortion
- gear noise prediction
- design allowable for gear steels
- effect of the ISF (isotropic surface finishing) process on gear durability

One thing the two institutions have in common is an A-list roster of sponsors, including Avio Group (Italy), Dana, Ford, Timken and Sikorsky Aircraft, among others.

We started off by asking Rao to what degree AGMA/ISO standards affect the status of GRI’s research

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activities. Turns out, it's sort of a good-better-best situation.

"Designing gears utilizing AGMA/ISO methods and procedures will give you a very functional gear with a long operating life," he says. "However, the aerospace industry has to design optimal gears because these gears have to fly in an aircraft and weight is a major consideration. That is where research groups (like GRI) come in. We work with the aerospace companies to support them in developing proprietary methods to design optimal gears for their applications."

As for Kahraman, he demurs to AGMA's aerospace committee on that question, but adds that "The aerospace community essentially has their own design methods that are related, but not identical, to the AGMA standards."

As cited in the MSNBC story, aerospace/defense funding and contracts are the lifeblood of not only good manufacturing jobs, but state-of-the-art research as well. Ever wonder how that works in other countries vs. United States? For many of them, think government assistance and sponsorship.

All of which begs the question—What, exactly, is the state of the nation's aerospace-related gearing research? It's a mixed review, in most respects.

But first, some perspective. Take Germany, for example, as explained by the GearLab's Kahraman.

"In Germany, the FVA (www.fva-net.de) is an industrial organization that funds as much gearing research as goes on in literally the rest of the world. Their government subsidizes this activity to a certain extent. It also supports universities with salaries (for professors). The FVA has about 190 members, all from Germany."

Kahraman goes on to point out the enviable fact that for the JSME's (Japan Society for Mechanical Engineers) motion and power transmission conference, their government sponsored 14 Japanese universities.

"Our number of universities involved with our ASME gearing conferences is only about five or six,"

but, he adds, "Our estimate is that little of the Japanese research has an aerospace motivation."

On the other hand, says GRI's Rao, "I do not believe that most European gear research is government-funded, and OEM funding is evident. The one venue of support for European gear research that is not very active here is their respective national trade associations."

Indeed, perhaps surprisingly to some, Rao prefers that government take a hands-off stance in most circumstances.

Apparently differentiating between the general revenue funds and the DOD budget, Rao says, "I do not believe that the federal government should get involved in funding research unless it directly relates to solving a problem that it needs solved. It is hard to say where that might go, under the current political climate."

Asked if GRI would like to see more government involvement, Rao states: "Gear research, especially as it relates to defense, is already U.S. government-funded. I do not see a more active role in the immediate future."

The GearLab's Kahraman agrees, adding by way of explanation that "We do not see (more U. S. funding) happening beyond the current funding that is driven by the Army and relates mainly to helicopters. Quite frankly, NSF (National Science Foundation) tends to steer the direction of university research, which in turn drives the types of faculty hired at (schools). NSF's priorities change quite often, but topics related to gears are not viewed as high priority. We think that the U.S. government, by and large, considers gearing to be a 'mature' technology and that all research should be paid for by industry."

Returning to the state of U.S. aerospace research, Kahraman responds, "The answer to this one is pretty subjective. When compared with the research going on at the German universities, there is only a pittance of U.S. gearing research going on. However, if one is speaking more of aerospace research, little of the German

research appears to be directed towards the aerospace industry, as the main driver is the automotive sector.

"Another way to answer this question is to look at how little academic gearing research is being performed in the U.S. Other than Ohio State and The University of Cincinnati, there are an extremely low number of graduate theses being written in gear-related areas in the past few years."

For GRI's Rao, the evaluation depends upon various application and industry sector issues.

"Thankfully, the aerospace industry is constantly pushing the gear design and performance envelope, with the aid of research," he says. "The automotive sector appreciates the value of gear research but cannot afford it at this time. While what constitutes research is in the eye of the beholder, most other industry sectors do not even realize they need research, simply because their gears work and the basic technology has been around forever. Consequently, my characterization of the state of gear research in the United States is just 'poor-to-fair'—a C-."

And when asked to identify the hottest areas of gear research here, the answers seems to depend on each institute's areas of emphasis.

"We are not sure that there is one area that is 'hotter' than any other," says the GearLab's Kahraman. "Our activities extend across a broad range of areas such as efficiency, durability, noise, etc. We have been active in all these fields, with some increases in our gear efficiency gear research due to fuel economy and carbon emissions issues."

For Rao's GRI, it's "Exploring new gear materials to improve performance (H3 i.e.—high strength, low carbon stainless steels and titanium) or to reduce costs (powder metal) are the 'hot' areas that we are involved in."

In closing, given the dismal, daily news reports on the economy, one might assume that aerospace research is taking a funding hit. And that is true—but only to an extent; i.e., it could be worse.

"The economy has killed off research support from the non-defense sectors,"

says Rao. “While some discretionary projects have been terminated—even from the aerospace industry—research funding continues to be strong from this sector, at this time.”

At the GearLab, “We do not think that the economy has affected the aerospace companies that deal heavily with gearing like (the economy) has the rest of the country,” says Kahraman. “Our sponsorship has not lost any of our aerospace participants, and, in fact, we have seen a rise in sponsorship from aerospace companies.”

Despite Lean Crew, NASA Glenn Continues Grinding Out the Work

The Cleveland-based NASA Glenn Research Center (GRC) boasts research efforts that are cutting-edge. Originally founded in 1941 as the Aircraft Engine Research Lab of the National Advisors Committee for Aeronautics—and changed in 1999 to its present name—the facility works to: develop “a national resource capable of providing innovations in aircraft engine technology, and transitioning these innovations to U.S. industry for use in future propulsion system designs for commercial and military applications.”

Complementing the work done at the GearLab and GRI, GRC’s mission includes aeronautics, space research and fealty to tax payers. The GRC includes in its focus the following:

- to be valued as a leader in space flight systems development
- to be known for excellence in project management
- to excel in aeronautics and space research
- to become an integral part of the Ohio community and the nation

As done previously, we asked about the relevance of standards to what they do at Glenn.

In general, says Phil Abel, deputy branch chief of the tribology and components branch for Glenn, “Yes, we are very interested in the standards-setting process. I’ve seen in other areas the importance of establishing good standards. We’ve begun exploratory talks in getting involved. It’s a question of what would be our most appropriate

role at this point.”

We then asked about funding support for aerospace specific to gearing and received a less-than-optimistic response.

“I think, unfortunately, it’s pretty thin,” says Handschuh. “There’s us here at Glenn, and we’re talking about less than 10 people; and then there are a few universities—there’s (the GRI and Applied Research Lab) at Penn State University. You’ve got Ohio State University—the GearLab, which is really doing very well—and they have quite a few sponsors.”

But, Handschuh relates, (As opposed to the deep space side of things) “The (aerospace) budget is always tight, and aero has been getting squeezed for the last 10-plus years. There’s a few reasons: One is the NASA program in general stayed fairly constant for quite a few years. If you think about it—if you never got a pay raise for 10 years, what does that do to your possibilities for doing research? If NASA had kept up with inflation, the budget would probably be double what it is now.

“Now, there’s been this shift to get rid of the shuttle, and with that shift there’s a lot of money going into the space-related side. And then there’s other competing things even within NASA—like the Hubble (telescope),

earth science, etc.”

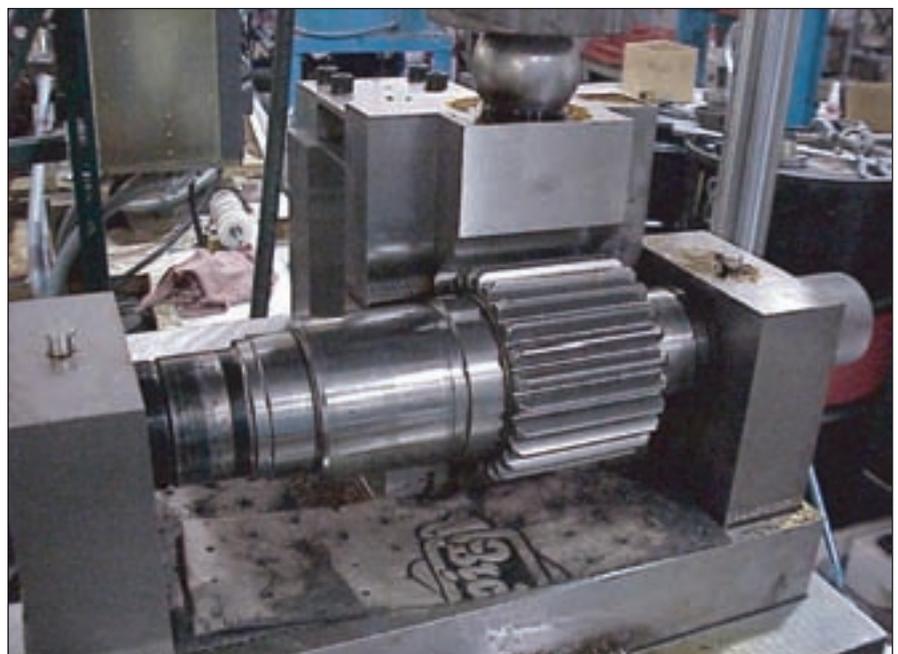
Says Abel, “The budget pressures within NASA have been fairly chronicled. The aero program within NASA has been receiving less emphasis over the last decade or so, (but) it sounds as if that may be reversing. But that’s at a policy level.”

Putting aside for now money issues, we got down to the nuts-and-bolts of the work being done at Glenn, especially currently. Handschuh lists a few projects:

“We are doing work in what they call ‘windage,’ he says. “Windage is the gears beating up the environment inside the gearbox—air and lubricant. But that is something we are trying to put some science to; there’s been a minimal amount of empirical work done, and we actually have a NASA-funded NRA (NASA research announcement). We have an in-house experimental effort ongoing in that area and we’re looking to apply some very modern CFD (computational fluid dynamics) tools to this problem.

“People have done things like CFD around a rotor and inside a gas turbine engine; we’re taking it one notch farther because gearing presents some real problems. We found a professor at (Penn State’s GRI and Applied

continued



Single-tooth bending fatigue test on a helicopter main transmission gear is performed at the Gear Research Institute (courtesy Gear Research Institute).

Research Lab), and I think he's made some very valuable contributions, just from the way you grid a problem like this. What we're really aiming for is not so much a tool, but to have direction on how to minimize windage losses in gearboxes."

"It's a hot area of research," adds Rosen. "(Another one) of the exciting things we are currently working on is a new bearing material, and it was just recently announced, so I can talk about

it now. It's a nickel titanium alloy which goes through a proprietary (heat treating) processing that suppresses the shape memory alloy properties and makes it machinable before processing and very hard afterwards. We have some samples which have the unique combination of properties being non-magnetic and highly corrosion-resistant—like silicon nitride, but conductive. For a niche application in, for example, instrumentation bearings, this may be



The Glenn Research Center's supersonic wind tunnel is used for state-of-the-art aerodynamics/aerospace research (courtesy NASA).

just the thing that's needed."

That said, we asked Handschuh for his evaluation of gearing research in this country—i.e., is the U.S. still No. 1?

"If you asked me that 20 years ago, I'd have said yes. Now I'd say that in some areas we're doing pretty well, but I see all the other countries at least being equal or surpassing us, (especially) Germany for gearing research.

"In the mechanical components area there's quite a concerted effort—in Germany, I know for sure—and probably Japan—that has been ongoing for a long time. The technical University of Munich has a large staff that dwarfs our team here, along with the professors and students that are working mechanical component-related research there. So that's a little disheartening. They're making good progress, but they have a lot of manpower."

We last asked about how OEM and other sponsorships work with Glenn on projects.

"We've worked directly with companies," says Handschuh, "but we're not going to test a widget because somebody says 'I'll pay you \$100,000 to test a widget.' It's more like if there's



Gearbox-related windage research is a priority at NASA Glenn (courtesy NASA).



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something we think is appropriate for us to work on for our charter. Sometimes they (sponsors, etc.) might supply us with test hardware, and our contribution and what we get paid to do is write papers and present our research. On one hand, they may be getting some testing done for almost nothing, but what we get out of it is (papers) and trying to provide information for U.S. technology.”

Adds Rosen: “Another form of cooperative research is where we’re both bringing resources to the table. If the company is interested in holding onto the data—keeping something proprietary—then NASA requires that it be essentially funded by the company. So there may be some situations where we enter into a fully refundable research agreement—but you won’t hear about those.”

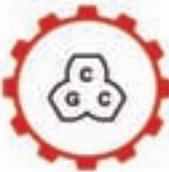
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