Eliot K. Buckingham

A second-generation gear master

Nancy Bartels

ELIOT K. BUCKINGHAM

EDUCATION
B.S. Massachusetts Institute of Technology, 1949.
M.S. University of New Mexico, 1951.

MILITARY SERVICE
U.S. Army, 1943–1946.
U.S. Air Force, 1951–1953.

MEMBERSHIPS
American Society of Mechanical Engineers.
Licensed Professional Engineer in the State of Vermont.

CAREER EXPERIENCE
University of New Mexico;
A.W. Haydon Co., Waterbury, CT;
Allied Control Co., Plantsville, CT;
Advanced Products Co., North Haven, CT;
Bryant Computer Products Co., Springfield, VT;
Established Buckingham Associates, Springfield, VT, 1960.

SELECTED ARTICLES & PUBLICATIONS

"Accelerated Life Tests," *Machine Design*, July 25, 1974.

"Avoiding Overdesign of Gears," *Machine Design*, Feb., 1980.

"Backlash in Gears," *Power Drive Engineering*, April/May, 1962.

"Controlling Tooth Loads in Helical Gears," *Machine Design*, Oct., 1975.

"Gear Cardiograph." with Weyman S. Crocker. Presented to the AGMA Aerospace Division, Feb., 1966.

"Gears in Action." American Pfauter Gear Process Dynamics Clinic, Oct., 1982.

"Guide to Worm Gear Types," *Product Engineering*, April 26, 1965.

"How Design Errors Influence the Functioning of Gear Trains," with Earle Buckingham, *Machinery*, August, 1964.

"Measurement of Surface Endurance Limit." International Powder Metal Conference, Orlando, FL, June, 1988.

Revised Manual of Gear Design, Sections I–III with Earle Buckingham, 1980–1981.

"Spur Gear and Worm Gear Sets," *Machine Design*, March 3, 1966, *Power Transmission Design*, May, 1966.

"Surface Endurance of Tufftrided® Materials," ASME Design Engineering Conference, April, 1975.

"Tables for Recess-Action Gears," *Product Engineering*, June 8, 1964.

"Taking the Guesswork Out of Worm Gear Design," *Machine Design*, March 20, 1975.

His resume reads like that of many gear engineers of his generation: the stint in the army during World War II; the break for college in the late 40s; deliberately vague descriptions of projects for the Air Force in the New Mexico desert in the early 50s; the corporate engineering jobs later on in the decade.

Then in 1960, long before the term became a euphemism for "laid off by a big corporation," Eliot K. Buckingham struck out on his own and became a gear consultant.

The idea of going one's own way in gear engineering was not new to Eliot Buckingham. In a sense, he was only following the family tradition. He is, after all, the youngest son of Earle Buckingham, author of *The Manual of Gear Design* and other staples of gearing literature. By the time *Gear Technology* spoke with him earlier this year, Buckingham had spent, quite literally, a lifetime in gearing.

Buckingham's view on the industry is something of a contrarian one. Perhaps this is inevitable, having spent most of his professional life analyzing and correcting other people's mistakes. A few weeks ago, he shared his perspective on the American gear industry.

The Last 50 Years

Buckingham sees only two new technologies that have come directly from the gear industry in the last 50 years. These are ITW's Spiroid® system and Novikov-Wildhaber gears.

Spiroid gears fill a niche between bevel, worm and face gear design. They are useful in applications where an offset greater than 20% of the gear radius is required. The pinion is tapered and

resembles a worm, and the gear member is a face gear with teeth curved in a lengthwise direction. The tooth inclination is like a helix angle, but is not a true helical spiral.

The Novikov-Wildhaber gears have parallel shafts and circular form teeth and are suitable for low-speed drives. They have applications in low-tech countries because they can be produced on ordinary milling machines, but their use is limited elsewhere.

"Beyond those two," says Buckingham, "most improvements have come from other technologies and been applied to gears."

Buckingham says that, like many others, the gear industry has been a great beneficiary of the space program. Many technologies developed there have made their way into common use throughout the industry. "Better techniques and better materials do improve things," he says.

"Back in the early 60s," he recalls, "we were retained by the Instrumentation Lab at MIT to work on a very accurate indexing device for a space sextant for the Apollo program. Our goal was to get a 4-inch diameter gear with an accuracy of about 5 arc-seconds. That's the equivalent of walking 3.5 miles with no more than an inch deviation off a straight line.

"We made a spur gear 4" in diameter, with 64 pitch and 256 teeth. We spent $40,000 to make the gear. That includes rebuilding a Fellows/Reishauer grinder. All the spindles were ground down for accuracy. We ended up with a drive accurate to 5 arc-seconds overall and 2–2.5 arc-seconds in any 90° quadrant.

"In the meantime, someone else was working with a company in New York on an optical disc and got it to an accuracy of .5 arc-seconds. That work contributed to the whole field of optical machine control."

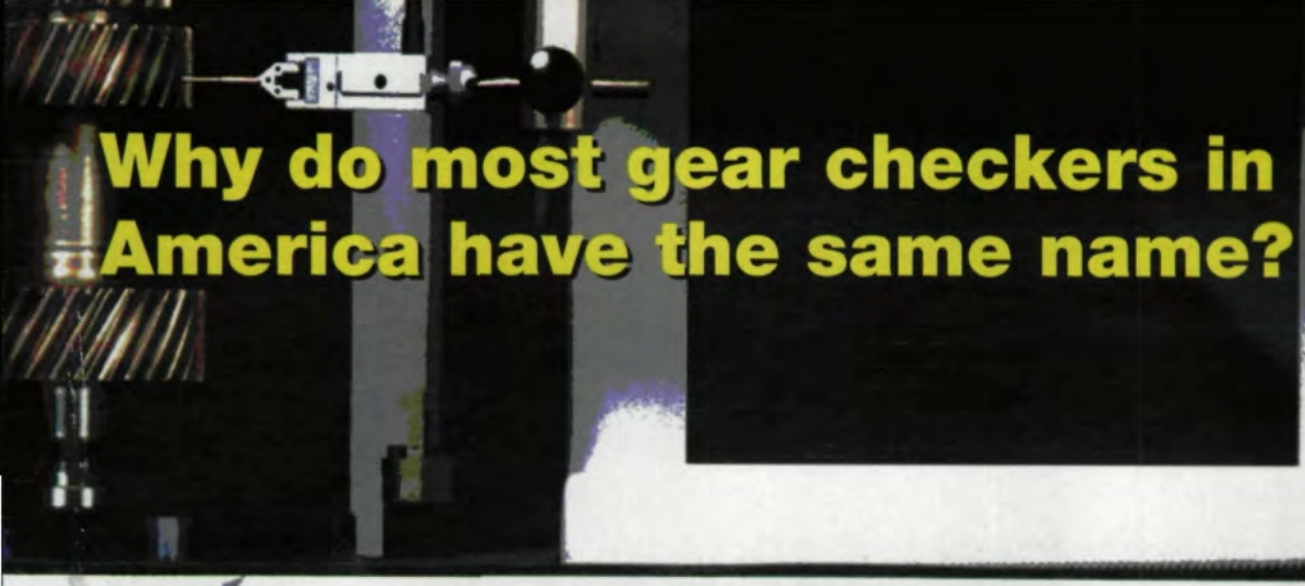
The American Approach

In spite of many improvements in material, technique and technology, Buckingham is less than sanguine about some aspects of American industrial development. For most of his adult life, American manufacturing, says Buckingham, has been its own worst enemy in some respects. "A friend of mine in manufacturing was fond of saying that when you came up with a new machine and took it to Europe, the first question you would be asked would be 'What's the principle behind it?' In the U.S., what they want to know is 'How much does it cost, and who else is using it?' We ask those questions too often here. We keep our eye too much on the bottom line.

"We don't do enough research. Many companies that 20 or 30 years ago had large research departments don't have one at all now. The only kind of research we're doing is product development.

"I have the feeling that we're big here into supporting planned obsolescence," Buckingham continues. "We tend to design products (not just gears) with the attitude that if the thing runs 4 or 5 years, then that's good enough."

Eliot K. Buckingham, his wife "Max" and their granddaughter Sabrina.



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Buckingham feels that this attitude is one that has cost the industry over the long run. "I spoke with a fellow who's in charge of a sugar refinery in Germany. He told me that the only time he ever had any gear failure problems were when he bought an American-made gearbox."

It also leads to the kind of shoddy business practice that leaves a bad taste in the mouth. "I was called in to consult for a power station out in New Mexico. The main bull gear was coming to pieces, and a local shop was trying to cut a replacement. The data they sent me didn't make any sense, so I went out to look at it. It turns out that the bull gear had been cut with a different hob than the pinion. A nonstandard hob had been used. I'm convinced the only reason it was done this way was so that the original supplier would be the only one who could provide a replacement."

Buckingham admits not every gear company is this way. "I've worked with products from gear companies where I've never seen a gear failure."

But this tendency to look to short-term profit runs against the grain for Buckingham. "Some people seem to think that they make their money selling gears," he reflects. "Actually, I think you make money on new gears and on the reputation for quality. One of the things my dad taught me was that, whenever I took a job, to work myself out of it as soon as possible. It's worked. People always come back. Sometimes the only way I know a job has been successful is that I never hear from the customer. Then five years down the road I'll get a call: 'You know that job you did five years ago? Can you do another one?'"

Buckingham on AGMA

Eliot Buckingham also takes a somewhat contrarian view of AGMA. While admitting the usefulness and even necessity of such an organization, he states, "Sometimes I think what we really need is an American Gear *Users* Association."

Buckingham parts company with AGMA over technical and philosophical issues.

"AGMA was started during the First World War by engineers who were interested in setting standards for gears and in

cooperating to develop better gear technology. Somewhere along the way, I believe in the 1930s, the association became dominated by salesmen rather than engineers," Buckingham says.

The approach to developing standards changed. The emphasis was placed on faster and cheaper methods of manufacture, rather than on producing better quality gears. Very little attention was placed on end use. What this means is that ". . . [the standards] give a base rating and then proceed to reduce it with service factors for various types of conditions. AGMA ratings are based on 'average' conditions, but how do you tell which specific application is 'average'?"

Buckingham says that a better way to design would be to "determine the maximum dynamic load that the gears will see in service and then calculate the beam strength and wear load capacity accordingly. That is general engineering practice for all load and stress calculations, except for gears."

Buckingham says that the dominance of sales personnel in the AGMA standards setting process has lessened. "In the last years good engineers have again become involved, and there is a real interest in furthering gear technology," he says. But, he adds, there is still a tendency on the part of some users to drift away from the AGMA standards and use their own whenever it is possible to do so. On the other hand, because AGMA

GROWING UP BUCKINGHAM

"What was it like growing up with someone obsessed with gears?" asks Eliot Buckingham. "I don't know. You'll have to ask my kids. The oldest was 12 and the youngest 5 when I got started [in business on my own]. My dad never brought his work home."

But he was very focused. Says Buckingham of the time when he and his father worked together: "He'd get completely wrapped up in his work. He had a very small office, and he'd be working, and I'd come in, work awhile and go out again, and he'd never know I'd been there."

On the other hand, growing up in the Buckingham household, it was hard to escape the gear theory entirely. When Earle Buckingham was working on his books, he would bring them home to the resident editor, his wife.

"My grandfather, my mother's father, was a librarian at Trinity College," Eliot Buckingham explains. "My mother used to say that books had to read smoothly aloud, so she used to read all my father's books out loud to him, so they could see how the words sounded."

Perhaps it was through just such an exercise that one of Earle Buckingham's most famous observations acquired the form we're most familiar with: "Man-made . . . laws have little in common with the laws of nature. They are incomplete, ambiguous, and often inconsistent; one often contradicting another. . . . Nature's laws, on the other hand, are complete and coordinated, whether we know them all or not. They are also self-enforcing and the penalty for violation is always exacted to the precise degree that the offense has earned. About the only thing in common between the laws of nature and those of man is that ignorance of the law is no defense."

does set the standards for the gear community, companies may feel forced to design to those standards, whether they reflect the best approach or not.

The Training Gap

One place where Buckingham does agree with many others is about the seriousness of the training gap for young engineers. In his view, there simply aren't enough places training young engineers in gearing, with the result that ". . . we'll fall farther and farther behind other countries. . . The industry needs people who know how to do the basics."

He acknowledges that there are some good training progams out there, but the problem is that they are offered on a hit-or-miss basis, and many people don't know about them. Buckingham also feels that many engineering curricula neglect training in gear design.

"There's good information out there," he says, "but people have to really work at getting it."

Gears of the Future

In spite of some of the problems facing the industry, Buckingham sees gears as being with us for a long time to come. "It's just a very economical way to transfer power at a reasonable cost," he says.

He is predicting a bright future for both plastic and powder metal gears. "Right now the big problem with plastic gears is that there is very little wear test data available for them."

He also admits to being "very enamoured" of powder metal gears. "We've found that the surface durability of powder metal is greater than that of base alloys. You can impregnate powder metal with lubricants. You can make alloys out of powder metal that you can't make otherwise."

Buckingham also suggests that he's already seen one of the most significant changes in the way gears are designed—the computer. "When my dad was writing the *Manual of Gear Design*, he calculated everything by hand from 15-place trig tables. He literally wore out an old hand-run calculator. Nowadays, you'd just do the whole thing on a computer.

"Before the computer, there were a lot of things we did by rule of thumb. You just didn't go beyond certain parameters. Now you can automatically check things out on the computer. You can take things right up to the edge of the manufacturing and performance capability."

One development Buckingham would like to see in the future is in the area of gears in the 40–45 Rc range, hardened to 50 Rc. Some are available now in high-volume production applications, but there is also a need for them in smaller lots, he says.

"What happens now is that there's this gap. You frequently have to go from the soft steels all the way up into hardened steels, and sometimes you'd like to have something in that gap area."

Buckingham sees changes in the gear industry coming slowly, which, he thinks, may not be altogether a bad thing. "Many problems are caused by solutions," he remarks.

He also likes to quote George Grant, who in 1890 commented about the advantages of using the involute over the old epicyclic gear: "The old system was easy to draw, easy to make, long established, and there was a reluctance to accept a change, particularly a change for the better."

Nancy Bartels is Gear Technology*'s senior editor.*

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