Gear Manufacturing Past, Present & Future

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"There is definitely a shrinking of demand for gears due to innovations and substitutions to replace gears. There are new drive techniques, for instance. You will see in a few years gear hobbing machines which manufacture gears but which do not have any gears within the machines. Conventional hobbing machines used to have more than 150 gears between the spindle drive of the cutter or the hob and the table, and today, if you count 5 to 10, this is the maximum, and it goes this way that one day there will be probably none. It is happening in the whole machine tool industry. Direct drives and the substitution of gear reducers due to more flexible drive systems."

—Peter Kozma, President, Liebherr Gear Technology, Inc.

Roughly 100 years ago, Cornelius J. Brosnan of Springfield, Massachusetts, invented and received the first U.S. patent for a paper clip. At about the same time, his fellow inventors were coming up with such marvels as the zipper, the safety razor and the typewriter.

While these inventions seem mundane compared to the differential gear hobber or the gear shaping machine, sometimes it helps to put things in perspective, and the fact is, these inventions came at around the same time. Gear manufacturing, like most industries, has seen more change in the 20th Century than it has in all our previous history. But these changes didn't take place in a vacuum. They've been affected, influenced and driven by industry, war, politics and consumer demand.

Our Recent History

"For sure, the biggest driver of change has been the mass production of automobiles," says Peter Kozma, president of Liebherr Gear Technology, Saline, MI. "Each part which goes into an automatic assembly line has to be exchangeable. Therefore, standards had to be developed, and standards such that every supplier could make the gears according to the standards and that they would fit into this mass production environment." Is it any wonder, then, that only eight years after Henry Ford introduced his Model T, the American Gear Manufacturers Association was formed?

1897 – *Robert Hermann Pfauter invents the first gear machine capable of cutting both spur and helical gears. This machine included a horizontal workspindle on vertical ways, a hob swivel, and a hob carriage feed along horizontal ways along the bed of the machine. The hob feed was accomplished manually with a crank on the end of a feed screw.*

1896 – *Invention of the Fellows Gear Shaper.*

1900 – *Invention of the paper clip.*

1903 – *Orville & Wilbur Wright conduct the first powered flight at Kitty Hawk, NC.*

1906 – *Gould & Eberhardt produces its first gear hobbing machine.*

1907 – *Lees Bradner produces its first successful gear machine, the No. 5 Gear Generator.*

1908 – *Max Maag develops the geometry of nonstandard involute spur and helical gears using rack-type cutters.*

1908 – *Ford began producing the Model T using an assembly line. "The introduction of the automobile had a far-reaching effect upon the machine tool industry and machine tool design. The demand for high-grade materials capable of withstanding shocks and stresses of high-speed cars, made it necessary to design machine tools capable of working the metals at economical speeds and feeds. These demands, in turn, showed weaknesses in machine tool design and construction. For example, it showed that cast-iron gears were entirely inadequate in many cases." – Machinery, September 1915.*

1910 – *Barber Colman ships its first hobbing machine, a No. 12 model*

1913 – *Maag grinding machines with saucer-shaped wheels are introduced. "This invention was important because it provided the first automatic compensation for the wear of the grinding wheel, making it the first and most famous automatic control system in the machine tool history." – from* Development of Gear Technology and Theory of Gearing, *by Faydor Litvin.*

1916 – *AGMA Founded.*

1916 – *Gleason invents a process for generating spiral bevel gears.*

1914-1918 – *World War I.*

Gary Kimmet, Vice President of Worldwide Sales for the Gleason Corporation, points to the 1970s oil embargo as having a big effect on gear manufacturers. It forced us to look at the fuel economy of our vehicles, and we saw a shift to smaller, front-wheel drive cars and away from rear-wheel drive gas guzzlers. For Gleason, this meant a significant decrease in the demand for the spiral bevel gears that drive rear axle differentials. But increased consumer demand for sport utility and 4-wheel drive vehicles reversed this trend in the early 1980s, Kimmet says.

Economic factors have certainly played a big role in the changes the gear industry has seen. In fact, the most important factor could be summed up in one word, says Bill Maples, marketing manager for Star Cutter Company. "Globalization," Maples says, pointing to the number of international corporate mergers and the number of major manufacturing companies moving their production locations outside the United States.

Joe Arvin, president of Arrow Gear Company, agrees. "The U.S. used to be able to sell because somewhere in the world they would buy our products." But in the 1970s, he says, foreign competition, particularly from Japan, began to challenge the ability of American companies to sell their products not only abroad, but at home as well. "They used to laugh at the Japanese products. It wasn't until the 80s that they realized what was going on," Arvin says.

A big factor in today's gear industry is the concern for the environment. "The changes in environmental requirements will definitely have an impact on the gear industry," says Liebherr's Kozma. We're seeing an increased demand for alternative energy sources, such as wind turbines, he says. "Environment also means to eliminate waste," Kozma says. "That means to increase efficiency, and this will also require transmissions in a different quality class."

The demand for energy saving, higher efficiency and increased power density have been the drivers of more and better gears as well as more economical ways of manufacturing them, says Dr. Hermann Stadtfeld, Vice President of Research and Development at Gleason Corporation. These demands have resulted in the 6-speed

"The basic trend will continue, and we will see a concentration in the gear industry. The remaining companies will be forced to modernize the equipment and update the technologies. The demand for gears will go down further. The typical example is the CVT gear box using less gears than a standard 5-speed gear box."
–Diether Klingelnberg, Chairman of the Board, Klingelnberg-Oerlikon Geartec Vertriebs GmbH.

"Gear makers in different parts of the world must learn from one another. European gear makers have a larger base of skilled people who understand the technology better because they can go to school for it and apprentice in it. The U.S. must concentrate on better educating its skilled workers."
—George Wyss, President of Reishauer Corporation

1919 – *AGMA publishes its first gear rating standard.*

1919 – *Lees Bradner develops the No. 10 Gear Tooth Grinder for grinding gears after hardening.*

1919 – *Barber Colman develops the No. 3 Hob Sharpening machine.*

1923 – *"The demand for high-performance spiral bevel gears grew at the beginning of this century as bevel gears began to be fitted in the powered rear axles of automobiles. The inventor Heinrich Schicht started to work in this field in 1907. In December 1921 he finally patented the simple method to produce spiral bevel gears using a helical hob. Klingelnberg took over the patent and employed the inventor Schicht, thus laying the foundation for his company's start in bevel gear hobbing technology. The first palloid hobbing machines were built from 1923 onwards." –Andreas Montag, marketing services, Klingelnberg-Oerlikon Geartec Vertriebs GmbH. Pictured at left is the 1923 Klingelnberg FK150 Universal Spril Bevel Gear Generating Machine.*

1923 – *Carl Mahr develops the world's first involute profile tester with variable adjustment of the base circle.*

1920s – *Lees Bradner develops its "rotary gear finisher," which pioneered the art of gear shaving.*

1922 – *Lees Bradner begins selling gear testers. These early instruments checked gear involute profile and tooth-to-tooth spacing.*

1929– *National Broach founded.*

1926 – *Ernst Wildhaber develops hypoid gearing at The Gleason Works.*

1932– *Rotary gear shaving introduced by National Broach.*

1937– *David Brown develops the Radicon worm gear drive.*

1919 – *Prohibition Ratified in the U.S.*

1927 – *The first working television is demonstrated.*

1926 – *Robert H. Goddard demonstrates the first liquid-fueled rocket.*

1929 – *U.S. Stock market crash.*

1930s – *Powder metal is first used to manufacture tungsten carbide cutting tools.*

1931– *Empire State Building completed.*

1933– *Prohibition Ends.*

1934– *Hitler comes to power in Germany.*

"We are ready for the challenges of the 21st Century. People are saying that the old-timers are leaving and the young upstarts don't know anything, and that's not true. You don't have to have the old school craftsmen with the computerized machines. We're better equipped in the U.S. than we were. The problem is being able to combat foreign competition."

—Joe Arvin, President, Arrow Gear

"I think that one of the biggest things that forced change in the United States is the influence of the Japanese manufacturing culture as it was perceived here. It's not that it was better, but it was truly perceived as being better. It revolutionized the thinking in the automobile industry, and accelerated changes through improvements."

—Bill Maples, Marketing Manager, Star Cutter Co.

manual automobile transmission, and the 5-speed automatic, he says.

Another big influence on the gear industry has been the emergence of computers and computing technology. Computers have allowed the development of tooth contact analysis, CNC controls, computer aided design and advanced metrology techniques, all of which continue to have a huge impact on the way gears are made.

The Turn of the Millennium

Today's gear industry is clearly very different from the gear industry of any other time. Machining gears out of metal was clearly the most common method 100 years ago. Today, this method of choice is being challenged by a far wider choice of materials—including, most notably, plastics and powder metals—and methods—including casting, forging, molding, grinding, EDM, stamping, sintering, fineblanking, laser and waterjet cutting. This is to say nothing of the choices we have today for improving a gear after it's initially formed, including the multitude of heat treating methods, coatings and finish machining processes.

"I think the industry is reinventing itself to adapt to the changes in technology," says Star Cutter's Bill Maples.

All of today's choices require the gear expert to obtain more and more education. "The gear industry requires a lot of technical skills to do a good job," says Gary Kimmet of Gleason. "It demands an ever-increasing movement in those technical skills. There is a continuing difficulty of having enough people who understand gears technically—how to design them so they are strong and quiet, and how to manufacture them."

"We don't see an overwhelming desire to go into the gear industry," Maples says. Parents would rather encourage their children to go into computers, medicine or law, he says. A career in manufacturing is not seen as one with promise. The AGMA has recently produced a video to promote the gear industry to young people deciding on a career path. The video is intended for high school and college guidance counselors, and according to Maples, it's the type of promotion the gear industry needs to do more of.

On the shop floor, at least, some see increases in machine tool technology as a way

1938 – *Gleason Formate method is invented by James Gleason.*

1939-1945 – *World War II.*

1939 – *The first digital computer.*

1942 – *The first controlled, self-sustained atomic reaction is conducted at the University of Chicago.*

1938 – *du Pont researchers invent Nylon. Today, plastic gears are one of the fastest growing segments of the market.*

1947 – *Dr. Edwin H. Land introduces the Polaroid camera.*

1949 – *China established People's Republic.*

1950s – *Powder metal is first used for gears.*

1950 – *Maag introduces spur and helical gear grinding by planar contact.*

1951 – *UNIVAC, the first commercial computer, is sold to the U.S. Census Bureau.*

1954 – *Darle Dudley publishes* Practical Gear Design.

1955 – *ITW introduces the Spiroid gear drive.*

1955 – *The first numerically controlled machine tools are on display at the National Machine Tool Show (precursor to IMTS).*

1956 – *Gear Honing introduced by National Broach & Machine.*

1957 – *Russians launch Sputnik, the first artificial earth-orbiting satellite.*

to offset the difficulty in finding expert gear makers. Many American workers are not as skilled as their European counterparts, says Ron Schomann, Vice President of LMT-Fette. "This costs American industry in terms of lower quality and broken tools. The development of electronic controls has allowed America to catch up because CNC machines are not as dependent on the operator to know as much as in the past. America has many unskilled people turning out good gears using this technology."

Joe Arvin of Arrow Gear agrees that machine tool technology can make a big difference. "People are saying that the old-timers are leaving and the young upstarts don't know anything." However, as the machines get better, we depend less on the skills of those old-timers, Arvin says. "You don't have to have old school craftsmen with the computerized machines."

But the rapid pace of change in today's technology requires an ever increasing need for continuing education. "The education we provide today to the next generation of specialists is the highest ever, and I believe that the learning phase in somebody's life will increase, not shorten. People will stay longer in the learning process," says Kozma.

The Next 1000 Years

"I cannot really tell you what sort of transmissions we will build twenty years from now," says Kozma. When you think what happened in the last 100 years, if you look back in the history books at how people were dressed and the tools they were using 100 years ago, and if you ask me to look forward 100 years from now, or even 50 years from now, and ask me how I think it will change, it's a very difficult question."

Kozma sees concern over the environment as being a key issue in the years to come. "In everything that we manufacture, we'll have to be focused on a higher environmental friendliness," Kozma says, "whether it's automobiles, whether it's mass transportation like airplanes or trains, or whether it's a refrigerator, and we have to consider when we're manufacturing it that there must be an environmental way of disposal. We cannot continue to make waste mountains, which have a tremendous negative impact on the environment."

"The gear industry requires a lot of technical skills to do a good job. It demands an ever-increasing movement in those technical skills. There is a continuing difficulty of having enough people who understand gears technically—how to design them so they are strong and quiet, how to manufacture them. The skill sets necessary to do a good job are not there. More training, something, has to be done to encourage people to go into the industry. The US is worse off than some countries, but the global trend is for less skilled people. It's going to lead us to having organizations providing those skills on an outsourcing basis."

—Gary Kimmet, VP Worldwide Sales and Marketing, Gleason

1960 – *Invention of the laser.*

1961 – *Development of Tooth Contact Analysis by Meriwether Baxter and Ernst Wilhaber at Gleason.*

1961 – *General Electric introduces cubic boron nitride (CBN).*

1963 – *Earle Buckingham publishes* Analytical Mechanics of Gears.

1963 – *John F. Kennedy assassinated.*

1964 – *Darle Dudley publishes his Gear Handbook.*

1966 – *Sumitomo introduces the cycloidal gear reducer in the United States.*

1968 – *Pfauter introduces carbide hobbing.*

1969 – *Apollo 11 astronauts land on the moon.*

1973 – *Oil embargo.*

1974 – *Pfauter introduces first NC hobbing machine, incorporating the "Electronic Gear Box."*

1976 – *Kapp CBN hob sharpening introduced to the U.S. (by American Pfauter).*

1976 – *Steve Wozniak and Steve Jobs build their first computer, the Apple I. "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."*

– Eliot K. Buckingham, excerpted from a 1997 interview.

"The development of electronic controls for gear machines has allowed America to catch up [in quality] because CNC machines are not as dependent on the operator to know as much as in the past. America has many unskilled people turning out good gears using this technology. We make up for low worker skills with high levels of technology."

—Ron Schomann, VP, LMT-Fette

This, our Millennium Outlook issue, has been one of the most interesting projects we've worked on in a long time. In our efforts, we've contacted many companies involved in the gear industry and asked them for help. We've tried to be as all-inclusive as possible, but we're sure we've overlooked some important people, processes or companies that should have been included. If we forgot you, we're sorry. Please send us a note, because we will continue to maintain and update our timeline of gear manufacturing achievements.

— The Editors

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Gary Kimmet adds that the trend toward globalization and increased competition will intensify. "I see consolidation of gear companies," Kimmet says. "The impact of globalization requires some level of critical mass in order to compete in the global market. That means trouble for some small gear companies."

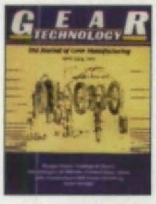
Many predict that the automotive industry will continue to drive trends in gear manufacturing. Electric vehicles and CVT technologies will certainly have an impact in the decades to come, although the exact nature of that impact is still uncertain. Electric vehicles may eliminate geared transmissions altogether by using direct drive technology. Continuously variable transmissions will probably require more accurate, more efficient gear systems.

"We foresee in the next years to come tremendous changes in consumer behavior," says Kozma. "There will be new products on the market which we don't even think of today. When you think about the changes only in the last 20 years as far as the consumer market is concerned, the speed in going into different products will require from us that we stay absolutely alert, to look forward, to sense in which direction the next generation will go."

The consensus seems to be that there will almost certainly be gears in a diversity of products for many years to come. How they're made, and in what quantity and at what quality will be determined only by time.

"I don't want to be negative," Kozma says, "but the demand for gears on a worldwide basis will in quantity reduce, but has to improve in quality and performance. All the products coming in the future will definitely require a higher class of quality. There will be substitutions to the gears which have been traditionally manufactured. There will be gear making methods which maybe have not been invented. There will be technologies to come and tools which are not on the market today. But gears will be required in the future. But I cannot tell you to what extent new technologies will eliminate gears."

Bill Maples puts a more positive spin on the industry's potential. "We haven't seen anything yet," he says. "I don't see why it's necessary to be anything but positive. The main thing people have to realize is that it's going to change." ○



1980 – *TiN coated gear tools introduced by Barber Colman, Star & Fette.*

1981 – *First CNC controlled combination lead/involute gear checkers introduced to U.S. (American Pfauter).*

1982 – *Kapp CBN plated wheel profile grinding introduced to U.S. & Canada (American Pfauter).*

1984 – Gear Technology *publishes its first issue.*

1987 – *Wafer Hobs are introduced by Pfauter-Maag Cutting Tools.*

1987 – *The First Gear Expo is held in Cincinnati, OH.*

1988 – *Opti-Gash Hobs are introduced by Pfauter-Maag Cutting Tools.*

1993 – *U.S. delegation becomes the secretariat to ISO TC-60.*

1994 – *Liebherr introduces dry hobbing.*

1994 – *Carbide Hobs introduced by Liebherr, Pfauter-Maag, Fette.*

1995 – *Harley-Davidson begins grinding transmission gears to reduce noise.*

1996 – *Launch of* **THE GEAR INDUSTRY HOME PAGE.**

1997 – *Gleason and Oerlikon debut dry cutting of spiral bevel gears.*

1999

1980 – *First Space Shuttle.*

1983 – *Compact Disk Debut.*

1989 – *Fall of the Berlin Wall.*

1990 – *Break-up of the Soviet Union.*

1989 – *Nelson Mandela elected president of South Africa.*

1980 – *The beginning of the rise of the sport utitlity vehicle. The greater demand for rear-axle differentials in 4X4 and SUV vehicles has a huge impact on the demand for spiral bevel gears.*