toothTIPS

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Progress in the design of globoidal worm drives is made with each passing year, but it's interesting to take a look back at its history and development over time.

ISO defines a globoidal worm drive as: "A gear whose flanks are capable of line contact with those of an enveloping worm, when meshed together with cross axes."

Last month we covered some of the various forms of cycloidal worm drives. However, in the United States the globoidal worm drive tended to be predominant. This gear form is quite old; da Vinci studied and sketched cycloidal and globoidal gears. But it was in 1765 that we first know of its successful application in a dividing engine. The hourglass-shaped worm was cut by a straight sided tool set in the worm's axial plane and traveling in a circular path, the center of which was that of the mating worm gear. The 13-inch diameter gear had 360 teeth. Invented by the clock maker Henry Hindley, his name has become associated with a specific design of globoidal worm. Smeatson wrote that "The threads of this screw are not formed upon a cylindrical surface, but upon a solid, whose sides are terminated by arches of circles, the screw and the wheel being ground together as an optic glass to its tool, produced the degree of smoothness of motion that I observed and lastly, that the wheel was cut from the dividing plate."

The gear form has also been known as encircling, hourglass, and double-enveloping. Current standards have established the correct terminology as "globoidal," a name first introduced by Dr. Reuleaux—director of the Royal Industrial Academy, Berlin—in 1876. In 1883 the U.S. government adopted this form for shock loads and minimum backlash. The worm had straight sides in its axis and conformed to the curvature of the wheel. Willis, Sellers, Lewis, and Thurston also studied and tested globoidal worm drives.

The objections of the time involved the difficulty in assembly and alignment. Longitudinal displacement caused one gear to cut into the other. The poor workmanship required excessive backlash in the gears. The first major improvement was an 1878 U.S. patent based on Stephen A. Morse's work on a machine tool to cut globoidal worm threads. The Philadelphia company Clerm and Morse built an improved machine in 1882; the worm was formed into a cutter and then used to finish the wheel. It was also alleged at the time—and later disproved—that the advantage lay in the fact that the whole side of every thread in the meridian plane is always in contact with the adjacent tooth. Grant wrote it was "erroneously stated that the worm fits and fills the gear on the axial section… contact may be linear."

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In 1910, Dr. W.F. Lanchester designed a globoidal worm for use in the rear axle drive of his automobiles. They were made to the practice of the Keystone-Hindley Gear Co., and the included angle varied with the number of threads. A single thread used 29˚, double and triple 35˚, and quadruple 37½˚. Some multiple thread gears could have angles as high as 52˚. The more efficient Lanchester gears had a slope of 1:2. In June 1914 John L. Woods' article in *American Machinery* provided a detailed method for calculating the strength of the Hindley worm. In 1922 Ernest Wildhaber invented a globoidal worm primarily for accurate indexing drives, in which the hob and worm thread surfaces are generated by spur or helical planes in an orthogonal rotation. The "Wildhaber" gear can be a disc with straight notches cut in the rim. The worm is generated from a flat-sided cutter or grinding wheel. The drive was also very popular for power drives, being simple to produce and measure accurately. Also at the time the gear was modified with a "second cut" to reduce the contact at both ends—enlarging the diameter in which the tool traveled was considered to be a trade secret.

By the thirties globoidal drives had developed into either a plane or cone design. Current AGMA standard 6035-A02 does not include the Wildhaber, only the Hindley, and the more recently designed forms that do not use a constant base circle to form the tooth profiles. A major development occurred at the Norfolk, Virginia, shipyard in 1920, when Samual I. Cone developed the globoidal gear that still bears his name and was patented in 1930/31/32. Cone's method eliminated the need for heavy undercutting. Also in the thirties two hobs were used and fed into the blank from opposite directions. At the correct depth one hob rotated in one direction, cutting the form at the tooth front, while rotating in the opposite direction the other hob formed the flank at the rear of the tooth.

Globoidal designs and manufacturing techniques were further advanced in the latter part of the 20th century. In 1959 Haseg introduced a worm with the inlet and outlet portions removed to evenly distribute the load. In 1980 tests to improve load sharing were conducted by Greening, Barlow, and Loveless. A simple manufacturing approach by using a two-tooth cutter was proposed by Professor Simon 1973-88. Wildhaber drives were modified by Ishida in 1978 and Ye in 1990. Grinding the Wildhaber gear was researched by Sakai in1978/80, Zhang and Qin in 1988, and Ye in 1990. A new German patent was awarded in 1969, to Pavlov in 1975, Maki in 1980, and to Sakai for when the worm or hob is enveloped by the conical surface of a milling or grinding wheel. Research on when the worm and hob thread surfaces are enveloped by surfaces of revolution from circular arc profiles of "Torus" milling and grinding wheels were conducted by Hu and Wand in 1988, and Kobyashi in 1993. In 1994 "Cone" introduced units with vastly improved ratings. Sumitomo claimed to be the first manufacturer with carburized, hardened and ground globoidal gears. Development of this gear form continues to be a subject of interest.

ABOUT THE AUTHOR:

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