

NON-CIRCULAR GEAR

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Abstract

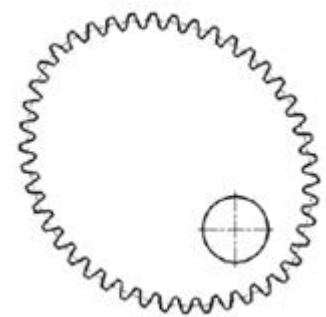
A non-circular gear (NCG) is a special gear design with special characteristics and purpose. While a regular gear is optimized to transmit torque to another engaged member with minimum noise and wear and with maximum efficiency, a non-circular gear's main objective might be ratio variations, axle displacement oscillations and more. The number of possible uses is limited only by the inventor's imagination and includes textile machines, potentiometers and CVTs (continuously variable transmissions).

Non-circular gear example

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A regular gear pair can be represented as two circles rolling together without slip. In the case of non-circular gears, those circles are replaced with anything different from a circle, which is how NCG got its name. This is also the reason NCG in most cases is not round, however round NCGs looking like regular gears are possible too (small ratio variations result from meshing area modifications).

Generally NCG should meet all the requirements of regular gearing, but in some cases, for example variable axle distance, could prove impossible to support and such gears require very tight manufacturing tolerances and assembling problems arise. Because of complicated geometry, NCGs are most likely spur gears and molding or electrical discharge machining technology is used instead of generation.



South Pointing Chariot



South Pointing Chariot (replica)

Supposedly invented sometime around 2600BC in China by the Yellow Emperor Huang Di, the South Pointing Chariot (*Zhi Nan Ju* ???) is widely regarded as the most complex geared mechanism of the ancient world. The chariot is a two-wheeled vehicle,

upon which is a pointing figure connected to the wheels by means of differential gearing. Through careful selection of wheel size, track and gear ratios, the figure atop the chariot will always point in the same direction.

Legend

Legend has it that Huang Di, credited as being the founder of the Chinese nation, lived in a magnificent palace in the Kunlun Mountains.

There was also at this time another tribal leader, Chi You, who was skilled at making weapons and waging war. He attacked the tribe of Yan Di, driving them into the lands of Huang Di. Huang Di was angered by this and went to war with Chi You, initially suffering several defeats. At some stage in the fighting, Chi You conjured up a thick fog to confound Huang Di's men, however the South Pointing Chariot was used to find their way, and they were ultimately victorious.

Timeline

The South Pointing Chariot has been invented and reinvented at many times throughout Chinese history. Below is a partial timeline of the major events:

Year	Event
2634 BC	According to Legend, Huang Di, the Yellow Emperor designs the South Pointing Chariot. It is built for him by the craftsman Fang Bo.
1115 BC	During the reign of the Duke of Chou the Chinese Minister of State, Chou Kung, gives five such devices (called Chih-Nan) to ambassadors of Yüeh-Shang to get them back home.
120 .. 139	Chang Hêng reinvents the vehicle.
220 .. 265	Two scholars prove before the court that such a vehicle is impossible.
233 .. 237	Ma Chün constructs a working vehicle for emperor Ming Ti.
300	Tshui Pao reports, that the construction is described in a book (not preserved) named Shang Fang Ku Shih.
334 .. 349	Hsieh Fei makes one for emperor Shih Hu.
394 .. 416	Linghu Shêng makes one for emperor Yao Hsing.
417	Linghu Shêng's vehicle is captured by emperor An Ti. It is reported that (at this time) there is no (longer any) machinery, but only a man inside who turns the figure.
423 .. 452	Kuo Shan-Ming fails to make one for emperor Thopa Tao.
423 .. 452	Ma Yo succeeds, but is killed by Kuo Shan-Ming.
478	Tsu Chhung-Chih makes a new improved (bronze gears) vehicle for emperor Shun Ti.
658	Buddhist monk Chih-Yü (or Chiyu) constructs vehicle for Japanese emperor Wu.
666	Monk Chih-Yu constructs another vehicle for Japanese emperor Wu.
806 .. 821	Chin Kung-Li presents a south-pointing carriage to emperor Thang.
1027	Engineer Yen Su (member of the "Board of Works") describes his construction (5 cogged, 4 non-cogged gear wheels, 18 soldier-drivers).
1088	Su Sung constructs a water wheel clock, using an escapement.
1107	Chamberlain Wu Tê-Jen (Wu Tê-Lung or Wu De Ren according to other sources) presents a specification (24 cogged, 4 non-cogged gear wheels), which is successfully built twice.
1341	Chu Tê-Jun describes a jade figure as (part of?) a miniature south-pointing carriage.
1720	Joseph Williamson uses differential gear in clock.
1834	J. Klaproth writes to Alexander von Humboldt, noting the south-pointing chariot chih-nan-ch'ê,

	but assumes that a magnetic compass is hidden in the little doll.
1879	Mr. Starley first uses differential gear in a vehicle.
1909	Professor Giles points out, that the directional property of the south pointing chariot was effected by a mechanical system, and not by magnetism.
1909	Professor Bertram Hopkinson (Cambridge) remarks, that some mechanism would have been required to ensure that the gears connected to the chariot wheels at right and left were engaged or disengaged when the chariot turned right or left. After some years of study, he declares that Yen Su's specification is insufficient to build a working model.
1910	The first mechanical navigation aide "Jones Live Map" is invented. Like in the south-pointing chariot the movement of the road wheels is geared down, but this time to show the relative position of the vehicle on a map.
1924	Rev. A. C. Moule (Cambridge) proposes a realization of Wu Tê-Jen's specification, where the chariot is allowed to drive only straight lines. For each turn it is stopped, a gear connected and the turn done on the spot, the pointer now being corrected automatically.
1924	K. T. Dykes is the first to propose a differential gearing, arguing that the clutch mechanism proposed by Moule is "slow and complicated to drive".
1932	Dr. J.B.Kramer discovers references to the mechanical nature of the south-pointing chariot and declares, that the Chinese therefore did not invent the magnetic compass.
1932	George Lanchester proposes that the ancient machines (Ma Chün notably) embodied some kind of differential gear. He builds a working model to prove his concept.
1937	Wang Chen-To (Wang Zhenduo according to other sources) proposes a realization of Yen Su's specification and builds a working model from it.
1948	Pao Ssu-ho (Bao Sihe according to other sources) proposes another reconstruction.
1955	F.W. Cousins introduces the Lanchester reconstruction to a broader public, namely the Meccanico fans.
1956	J. Coales points out, that by hanging a carrot from the emperors hand, the south-pointing chariot would become self-steering!
1977	Professor André Wegener Sleeswyk publishes a scientific essay on the historic chariots. He proves their feasibility exactly to the words in the ancient texts.
1978	Mr. Alan Partridge starts a contest in The Meccano Magazine for the design with the fewest gears. It is shown subsequently that no gears are necessary at all!
1979	Mr. Noel C. Ta'Bois publishes a concise treaty on the theoretical aspects. Working specimen are shown, which do not adhere to the "width equals wheel diameter" rule.
1979	Lu Zhiming produces three reconstructions based on differential gears.
1980	Mr. Don Frantz from New York re-discovers the south pointing chariot, builds models along the Lanchester path and manages to place them in the Museum of the Province of Xian.
1982	Yan Zhiren builds another model, stressing that only differential gears provide the accuracy reported by the old writings.
1991	Mr. M. Santander from Spain proposes to use the chariot to teach students the basic concepts of parallel transport and curvature. En passant a mathematical model is given for Mr. Nuttall's design.

References:

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