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Original Research Paper

Presentation of a Mechanism with a Maltese Cross (Geneva Driver)

[1]Florian Ion Tiberiu Petrescu, [2]Taher M. Abu-Lebdeh and [3]Antonio Apicella

[1]*ARoTMM-IFToMM, Bucharest Polytechnic University, Bucharest, (CE), Romania*
[2]*North Carolina A and T State Univesity, United States*
[3]*Department of Architecture and Industrial Design, Advanced Material Lab, Second University of Naples, 81031 Aversa (CE), Italy*

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Corresponding Author:
Florian Ion Tiberiu Petrescu
ARoTMM-IFToMM, Bucharest Polytechnic University,
Bucharest, (CE), Romania
Email: scipub02@gmail.com

Abstract: The paper presents briefly a mechanism with a cross of Malta. The mechanisms with a Maltese cross (Geneva driver) are present in automation, robotics, mechanical transmissions, continuous variable transmissions, old clocks, especially when it comes to transmitting forces and high moments, being used instead of or with the gears. The geometry of the mechanism consisting of two elements, the kinematics and the forces appearing in this mechanism with a fourth-class upper coupler, are studied very briefly. By studying the forces that appear within the mechanism couple, a dynamic study is also carried out.

Keywords: Maltese Cross, Geneva Driver, Robots, Manipulators, Automation, Engines, Mechanical Transmissions, Kinematics, Forces, Dynamics, Dynamic Kinematics, Dynamic Forces

Introduction

The mechanisms with a cross of Malta (Geneva driver) are present in automations, robotizers, mechanical transmissions, continuous variable transmissions, old clocks, especially when it comes to transmitting forces and high moments, being useful instead of or with the gears. In Fig. 1 is presented a mechanism with a cross of Malta having a single entry.

Figure 2 presents such a mechanism having two entries.

Fig. 1: Mechanism with a cross of Malta with a single entry

In the early days, the Maltese cross mechanisms were used in mechanical mechanization and automation, realizing moments when the mechanism worked and moments when it stopped for a certain period of time, this being set by the number of inputs that the mechanism had (the number of pins of the leading element 1), the passageways number of the driven element 2 and the effective design of the entire mechanism.

Fig. 2: A mechanism with a cross of Malta having two entries

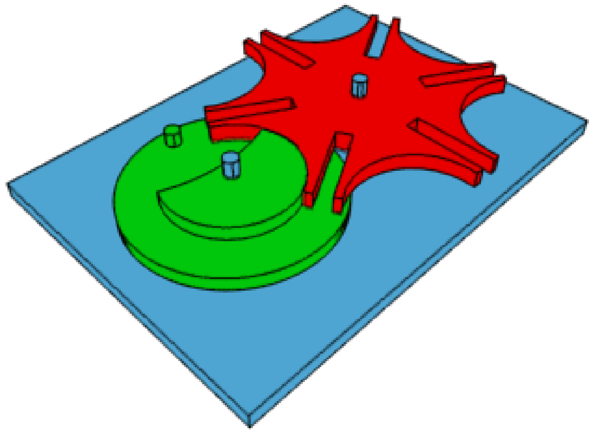

Fig. 3: An external mechanism with a Maltese cross, having one entry and six channels (a deformed cross)

The Geneva unit or the Maltese cross is a gear mechanism that translates a continuous rotation motion into intermittent rotating motion.

The rotary drive wheel is usually equipped with a pin that comes into an orifice on the other wheel (driven wheel) that advances it one step at a time. The main wheel also has a high circular locking disc that "locks" the rotating actuated wheel between the steps.

Figure 3 is showing a six-position (channels), a single entry, an external Geneva drive in operation.

The name, Geneva drive, is derived from the device's earliest application in mechanical watches, which were popularized in Geneva, being the classical origin of watchmaking industry.

The Geneva drive is also called a "Maltese cross mechanism" due to the visual resemblance when the rotating wheel has four spokes, since they can be made small and are able to withstand substantial mechanical stress. These mechanisms are frequently used in mechanical watches.

In the most common arrangement of the Geneva drive, the client wheel has four slots and thus advances the drive by one step at a time (each step being 90°C) for each full rotation of the master wheel. If the steered wheel has n slots, it advances by 360°/n per full rotation of the propeller wheel.

Because the mechanism needs to be well lubricated, it is often enclosed in an oil capsule.

One application of the Geneva drive is in film movie projectors and movie cameras, where the film is pulled through an exposure gate with periodic starts and stops. The film advances frame by frame, each frame standing still in front of the lens for a portion of the frame cycle (typically at a rate of 24 cycles per second) and rapidly accelerating, advancing and decelerating during the rest of the cycle. This intermittent motion is implemented by a Geneva drive, which in turn actuates a claw that engages sprocket holes in the film. The Geneva drive also provides a precisely repeatable stopped position, which is critical to minimizing jitter in the successive images. (Modern film projectors may also use an electronically controlled indexing mechanism or stepper motor, which allows for fast-forwarding the film.)

The first uses of the Geneva drive in film projectors go back to 1896 to the projectors of Oskar Messter and Max Gliewe and the Teatrograph of Robert William Paul. Previous projectors, including Thomas Armat's projector, marketed by Edison as the Vitascope, had used a "beater mechanism", invented by Georges Demenÿ in 1893, to achieve intermittent film transport (Bickford, 1972; Taimina, Historical notes).

Geneva wheels having the form of the driven wheel were also used in mechanical watches, but not in a drive, rather to limit the tension of the spring, such that it would operate only in the range where its elastic force is nearly linear.

If one of the slots of the driven wheel is occluded, the number of rotations the drive wheel can make is limited. In watches, the "drive" wheel is the one that winds up the spring and the Geneva wheel with four or five spokes and one closed slot prevents overwinding (and also complete unwinding) of the spring. This so-called Geneva stop or "Geneva stop work" was the invention of 17th or 18th-century watchmakers.

Other applications of the Geneva drive include the pen change mechanism in plotters, automated sampling devices, banknote counting machines and many forms of indexable equipment used in manufacturing (such as the tool changers in CNC machines; the turrets of turret lathes, screw machines and turret drills; some kinds of indexing heads and rotary tables; and so on). The Iron Ring Clock uses a Geneva mechanism to provide intermittent motion to one of its rings.

A Geneva drive was used to change filters in the Dawn mission framing camera used to image the asteroid 4 Vesta in 2011. It was selected to ensure that should the mechanism fail at least one filter would be usable (Bickford, 1972).

Materials and Methods

An internal Geneva drive is a variant on the design (Fig. 4). The axis of the drive wheel of the internal drive can have a bearing only on one side. The angle by which the drive wheel has to rotate to effect one step rotation of the driven wheel is always smaller than 180° in an external Geneva drive and always greater than 180° in an internal one, where the switch time is, therefore, greater than the time the driven wheel stands still.

A mechanism of this modern type is the spatial mechanism (Fig. 5) in which the movement and the transmission are made spatially and internally (Frăţilă *et al*., 2011; Pelecudi, 1967; Antonescu, 2000; Comănescu *et al*., 2010; Aversa *et al*., 2016a; 2016b; 2016c; 2016d; 2017a; 2017b; 2017c; 2017d; 2017e; Mirsayar *et al*., 2017; Cao *et al*., 2013; Dong *et al*., 2013; De Melo *et al*., 2012; Garcia *et al*., 2007; Garcia-Murillo *et al*., 2013; He *et al*., 2013; Lee, 2013; Lin *et al*., 2013; Liu *et al*., 2013; Padula and Perdereau, 2013; Perumaal and Jawahar, 2013; Petrescu and Petrescu, 1995a; 1995b; 1997a; 1997b; 1997c; 2000a; 2000b; 2002a; 2002b; 2003; 2005a; 2005b; 2005c; 2005d; 2005e, 2016a; 2016b; 2016c; 2016d; 2016e; 2013; 2012a; 2012b; 2011; Petrescu *et al*., 2009; 2016a; 2016b; 2016c; 2016d; 2016e; 2017a; 2017b; 2017c; 2017d; 2017e; 2017f; 2017g; 2017h; 2017i; 2017j; 2017k; 2017l; 2017m; 2017n; 2017o; 2017p; 2017q; 2017r; 2017s; 2017t; 2017u; 2017v; 2017w; 2017x; 2017y; 2017z; 2017aa; 2017ab; 2017ac; 2017ad; 2017ae; Petrescu and Calautit, 2016a; 2016b; Reddy *et al*., 2012; Tabaković *et al*., 2013; Tang *et al*., 2013; Tong *et al*., 2013; Wang *et al*., 2013; Wen *et al*., 2012; Antonescu and Petrescu, 1985; 1989; Antonescu *et al*., 1985a; 1985b; 1986; 1987; 1988; 1994; 1997; 2000a; 2000b; 2001; List the first flights, From Wikipedia; Chen and Patton, 1999; Fernandez *et al*., 2005; Fonod *et al*., 2015; Lu *et al*., 2015; 2016; Murray *et al*., 2010; Palumbo *et al*., 2012; Patre and Joshi, 2011; Sevil and Dogan, 2015; Sun and Joshi, 2009; Crickmore, 1997; Goodall, 2003; Graham, 2002; Jenkins, 2001; Landis and Dennis, 2005; Clément, Wikipedia; Cayley, Wikipedia; Coandă-1910, Wikipedia; Gunston, 2010; Laming, 2000; Norris, 2010; Goddard, 1916; Kaufman, 1959; Oberth, 1955; Cataldo, 2006; Gruener, 2006; Sherson *et al*., 2006; Williams, 1995; Venkataraman, 1992; Oppenheimer and Volkoff, 1939; Michell, 1784; Droste, 1915; Finkelstein, 1958; Gorder, 2015; Hewish, 1970).

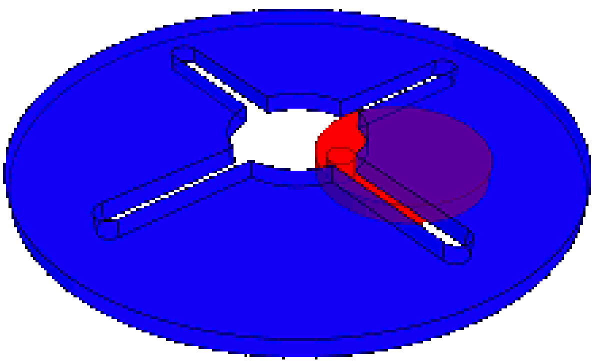

Fig. 4: An internal mechanism with a Maltese cross (Geneva drive), having one entry and four channels (a normal cross)

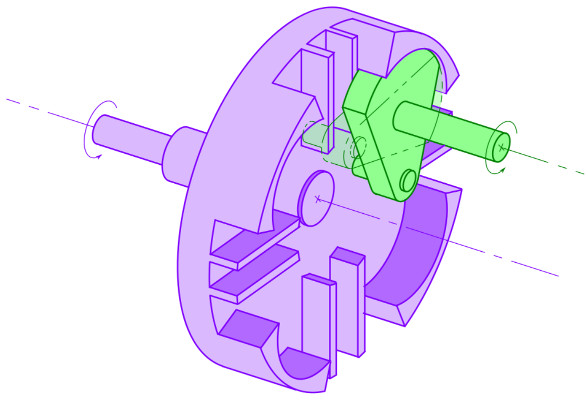

Fig. 5: An internal spatial Geneva drive mechanism, having one entry and four channels (a normal cross)

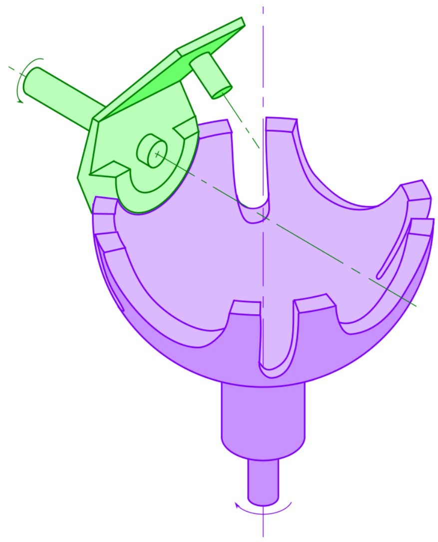

Fig. 6: A spatial spherical Geneva drive mechanism, having one entry and four channels (a normal cross)

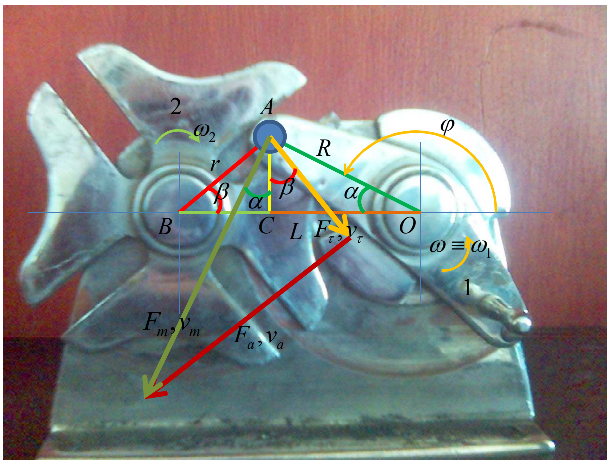

Fig. 7: The kinematic scheme of a Maltese cross mechanism (with two beginnings, two entries)

Another variant is the spherical Geneva drive (Fig. 6).

The kinematic scheme of a Maltese cross mechanism (with two beginnings, two entries) can be seen in Fig. 7, which also represents the distribution of forces on the mechanism.

Results and Discussion

The leading element 1 transmits the rotation motion of the Maltese cross 2. The F_m force perpendicular to A on the crank 1, $OA = R$, is divided on the element 2 into two components: A component F_t perpendicular to the crank $AB = r$ which is an active force, useful, power transmission, which produces the rotation of the Maltese cross; and another sliding component F_a which represents a loss of power of the coupling mechanism by the relative sliding of the two profiles corresponding to the two movable elements in contact.

The second element allows the bolt to slide on the leading channel 1, on that channel. Conversely, movement is not possible, because when the cross becomes a leading element, its motor force is divided into two components, much larger being the component pulling the element 1 by stretching (or compressing) it, producing a very large pressure between the two profiles generating a very high frictional force that does not allow the very small rotation component to rotate the element 1.

In addition, the component that should rotate the element 1 perpendicular to the OA in A is no longer oriented on the direction of the AB channel but on in another direction so that it has more of a reaction effect pushing back into the leading element 2 and thus causing the mechanism to lock. It follows that the Maltese cross mechanism is irreversible (it moves in both directions, but it can only transmit motion from the driver to the cross and not vice versa); he may also be able to use worm gear or ratchet mechanisms for steering mechanisms, counters, robot transmissions and so on. Write the relationships (1-3):

$$\begin{cases} F_\tau = F_m \cdot \cos(\alpha+\beta); AC = R\cdot\sin\alpha; OC = R\cdot\cos\alpha; \\ v_\tau = v_m \cdot \cos(\alpha+\beta); BC = BO - OC = L - R\cdot\cos\alpha; \\ \eta_{iD} = \dfrac{P_u}{P_c} = \dfrac{F_\tau\cdot v_\tau}{F_m\cdot v_m} = \dfrac{F_m\cdot v_m}{F_m\cdot v_m}\cdot\cos^2(\alpha+\beta) = \cos^2(\alpha+\beta) \\ \eta_{iD} = \cos^2(\alpha+\beta) \end{cases}$$
$$\begin{cases} \omega_2 = \dfrac{v_2}{r} = \dfrac{v_\tau}{AB} = \dfrac{v_m\cdot\cos(\alpha+\beta)}{\sqrt{R^2+L^2-2\cdot R\cdot L\cdot\cos\alpha}} \\ = \dfrac{R\cdot\omega\cdot\cos(\alpha+\beta)}{r} \\ \sin\beta = \dfrac{R}{r}\cdot\sin\alpha; \cos\beta = \dfrac{L-R\cdot\cos\alpha}{r} \end{cases} \quad (1)$$

$$\begin{cases} \cos(\alpha+\beta) = \cos\alpha\cdot\cos\beta - \sin\alpha\cdot\sin\beta = \\ = \cos\alpha\cdot\dfrac{L-R\cdot\cos\alpha}{r} - \sin\alpha\cdot\dfrac{R\cdot\sin\alpha}{r} = \\ = \dfrac{1}{r}\cdot\left(L\cdot\cos\alpha - R\cdot\cos^2\alpha - R\cdot\sin^2\alpha\right) = \dfrac{L\cdot\cos\alpha - R}{r} \\ \Rightarrow \cos(\alpha+\beta) = \dfrac{L\cdot\cos\alpha - R}{r} \\ \cos^2(\alpha+\beta) = \dfrac{(L\cdot\cos\alpha - R)^2}{r^2} \\ = \dfrac{L^2\cdot\cos^2\alpha + R^2 - 2R\cdot L\cdot\cos\alpha}{L^2+R^2-2\cdot R\cdot L\cdot\cos\alpha} \\ \eta_{iD} = \cos^2(\alpha+\beta) = \dfrac{L^2\cdot\cos^2\alpha + R^2 - 2R\cdot L\cdot\cos\alpha}{L^2+R^2-2\cdot R\cdot L\cdot\cos\alpha} \\ \omega_2 = \dfrac{R\cdot\omega\cdot(L\cdot\cos\alpha - R)}{L^2+R^2-2\cdot R\cdot L\cdot\cos\alpha} = \dfrac{R\cdot L\cdot\cos\alpha - R^2}{L^2+R^2-2\cdot R\cdot L\cdot\cos\alpha}\cdot\omega \end{cases} \quad (2)$$

$$\begin{cases} \omega_2\cdot\left(L^2+R^2-2\cdot R\cdot L\cdot\cos\alpha\right) = R\cdot L\cdot\cos\alpha\cdot\omega - R^2\cdot\omega \\ \varepsilon_2\cdot\left(L^2+R^2-2\cdot R\cdot L\cdot\cos\alpha\right) + \omega_2\cdot 2\cdot R\cdot L\cdot\sin\alpha\cdot\dot{\alpha} \\ = -R\cdot L\cdot\omega\cdot\sin\alpha\cdot\dot{\alpha};\ \ \alpha = \pi - \varphi;\ \ \dot{\alpha} = -\omega \Rightarrow -\dot{\alpha} = \omega \\ \varepsilon_2 = -R\cdot L\cdot\sin\alpha\cdot\dfrac{\omega + 2\cdot\omega_2}{L^2+R^2-2\cdot R\cdot L\cdot\cos\alpha}\cdot\dot{\alpha} \\ \varepsilon_2 = R\cdot L\cdot\sin\alpha\cdot\dfrac{1+2\cdot\dfrac{R\cdot L\cdot\cos\alpha - R^2}{L^2+R^2-2\cdot R\cdot L\cdot\cos\alpha}}{L^2+R^2-2\cdot R\cdot L\cdot\cos\alpha}\cdot\omega^2 \\ \omega_2 = \dfrac{-R\cdot L\cdot\cos\varphi - R^2}{L^2+R^2+2\cdot R\cdot L\cdot\cos\varphi}\cdot\omega \\ \varepsilon_2 = R\cdot L\cdot\sin\varphi\cdot\dfrac{L^2-R^2}{\left(L^2+R^2+2\cdot R\cdot L\cdot\cos\varphi\right)^2}\cdot\omega^2 \\ \varphi_2 = -\arcsin\left(\dfrac{R\cdot\sin\varphi}{\sqrt{L^2+R^2+2\cdot L\cdot R\cdot\cos\varphi}}\right)\cdot\dfrac{\varphi}{\pi-\varphi} \end{cases} \quad (3)$$

Conclusion

The paper presents briefly a mechanism with a cross of Malta. The mechanisms with a Maltese cross (Geneva driver) are present in automation, robotics, mechanical transmissions, continuous variable transmissions, old clocks, especially when it comes to transmitting forces and high moments, being used instead of or with the gears.

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Author’s Contributions

All the authors contributed equally to prepare, develop and carry out this manuscript.

Ethics

This article is original and contains unpublished material. Authors declare that are not ethical issues and no conflict of interest that may arise after the publication of this manuscript.

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