PHYSICS OF ANCIENT INDIAN RING WEAPON

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Various types of small arms were used in ancient India. Before the use of gunpowder, wars were fought mainly with swords, bows and arrows. While a sword or knife is still used for close combat, projectile weapons like bow and arrow were all replaced by guns. Indian scriptures describe a weapon thrown by hand at the enemy, known as *Chakram* (Rudnick). Although mythological texts mention this to be a weapon of Lord Vishnu, in medieval times, historical work *Akbarnama* has a war-scene depicting the use of *Chakra*. In pre-modern times, Sikh warriors have used *Chakra* made of metal ring with saw-toothed (serrated) edge. *Chakra* rotates and flies. Some of the features of stability and flight can be accessed by knowledge of school physics. Rotational motion is taught with examples of rolling wheel spinning of top, etc. The spinning ring attains the rigidity in a way similar to the rigidity of a spinning top. The ring also flies. So, unlike a solid metal ball, it attains more range. It gets lift due to its motion in the air. Some of the old rings have airfoil different than flat sheet. It generates more lift compared to a flat plate. The early users and inventors of this weapon were perhaps concerned with the performance. With the advancement of science and technology, it has been discovered how it gets stability during flight and what gives it a lift (Lorenz). Modern variant of this ancient weapon are recreational toys. For weapon, metals like iron, copper, etc were used, while for toys, plastic is the material of choice due to safety concerns. In 1957 a toy manufacturer obtained trademark–Frisbee for their flying disc toy. In order to improve its range, an inventor found the reference of ancient Indian weapon and designed the product in a ring shape, with asymmetric curved top.

Keywords: Rotational motion, Flight, Weapon, Spin

Introduction

Indian mythology describes Lord Vishnu having *Chakra* as one of his weapons. According to mythology Lord Vishnu's four hands contain a conch, a lotus, a mace, a *chakra* known as *Sudarshan Chakra*, which is in his right hand. Apart from mythology, war scenes depicting the use of circular objects can be found in illustrations in historical book *Akbarnama* also.

Fig. 1. Chakra in miniature in Akbarnama

In modern history, too, Sikh soldiers using the *Chakra* and its use in battlefield have been described by Mundy and quoted by Egerton as follows:

"But the arm that is exclusively peculiar to this sect is quoit. It is made up of a beautiful thin steel, sometimes inlaid with gold, in using it, the warrior twirls it swiftly with the forefinger, and raising his hand over his head, launches it with such deadly aim."

Fig. 2. Twirling the quoit just before throwing (From Egerton)

Egerton also quotes 16th century author Barbosa "the fighting men of Delhi, carry steel wheels (*chakram*), and he describes the way in which they are carried, seven or eight in the left arm, and spun on the fingers on the right hand."

During World War I, the appearance and use of ring weapon is reported in Popular Mechanics in 1916, "A weapon, new to the armies of Europe, is the *Chakkar* of the Sikh warriors from India who are fighting with the allies in France. The Indian fighters carry this weapon on their turbans. It looks very much like an ordinary quoit, but has an edge like a razor, The Sikh throws the *Chakkar* by twirling it around in his hand and then suddenly releasing it. Whirling through the air and revolving horizontally, it makes a terrible wound on striking. At 12 yd. a *Chakkar* will cut a 2-in bamboo into two" (Windsor, 1916).

Fig. 3. Indian soldiers using ring weapon during World War I

Flight of the ring: Aerodynamics

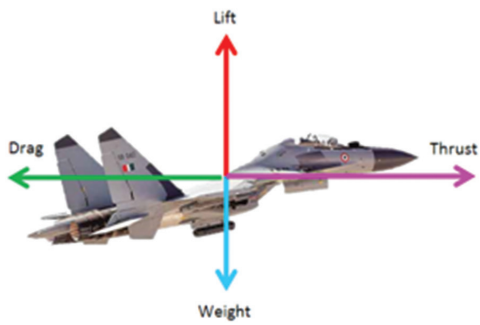

Fig. 4. Forces on an aircraft

Four forces used to describe the physics of flight of an object are as follows: One of the forces is gravity or weight of the object acting vertically downward. Second is the thrust generated by engines or through muscle power, as in the case of birds. Last two forces are related to aerodynamics, which are drag and lift. Drag is generated because air resists the flow of object, and lift is generated because air passing through top and bottom faces of the object generates different pressures, and when upward pressure is more than the downward pressure, a lifting force is generated. Aerodynamics performance depends on wing cross section (Kamaruddin, 2018).

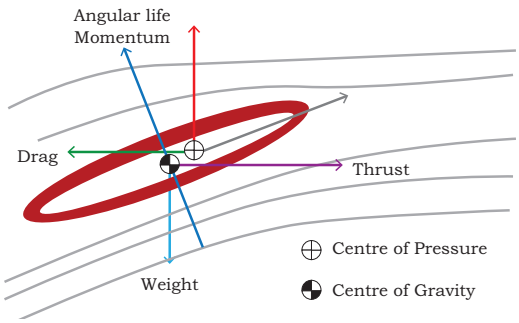

Fig. 5. Aerodynamic forces in flying ring

Stability of the Ring: Gyroscopic Stability

In the case of a flying disc, or ring, the centre of pressure is shifted away from the centre of mass towards the direction of motion. This should cause disc to become unstable; however, when the disc is spinning, it gets stability in a manner similar to a spinning top. This is also termed as gyroscopic stability.

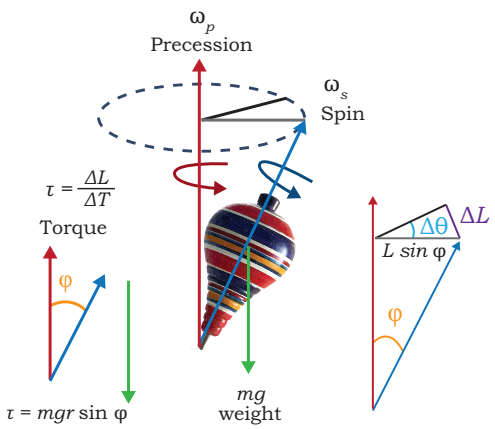

Fig. 6. Forces and torques acting on the spinning top

The full understanding of the motion of spinning top can be gained using Euler angles and Newton-Euler Equations (Goldstein, 2000; Upadhyaya, 2005). However, simple derivation of precession frequency is possible if certain assumptions are made like steady and slow precession. Precession frequency of the ring can be found from the following equation,

$$\omega_p = \frac{mgr\ sin\ \varphi}{I\omega} = \frac{gr\ sin\ \varphi}{a^2\omega}$$

As can be seen in the spinning toy top, as the top slows down, its precession becomes faster. In other words, spin angular frequency is inversely proportional to precession angular frequency. In case of fast spinning top, i.e., when spin frequency is much higher than precession frequency, average precession frequency is also given by the above equation.

The torque acting on the top will cause a stationary top to topple, while in spinning top, same torque produces precession of the angular momentum around the vertical axis passing through its resting point. To appreciate the problem of the stability of an object spinning under gravity, an instructional box is given in physics text book of Class XI. The bicycle wheel shown in the following figure does not fall even if the supporting rope is removed. Instead of falling down, it starts precessing.

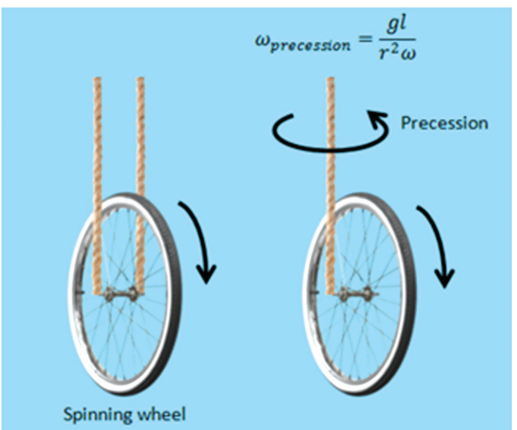

Fig. 7. Precession of bicycle wheel

From Disc to Ring: Evolution of a Toy

Modern variant of this ancient weapon are recreational toys. Its history goes like this. In 1871, W.R. Frisbee used to sell pie in a tin can near the Yale University. Students used to throw pie boxes made of tin in their free time and enjoy the range of its flight in the air. This became a popular past time. Later on, Frederick Morrison started selling empty cans. Morrison was a pilot in the US Army Airforce and after the World War II in 1948 he came up with an aerodynamically improved design and used butyl stearate material to make discs. Afterwards, polypropylene was used to make discs. In 1957, toy manufacturer Wham-O purchased his idea and started making flying disc toys with the trademark-Frisbee (Bloomfield, 1999; Morrison; 2005).

For making the ring weapon, *Chakra*, metals like iron, copper etc., were used, while for toys, plastic is the material of choice due to concerns of safety. Aerodynamics of disc wing has been presented by many authors (Morrison, 2005; Scodary, 2007; Schuurmans, 1990; Abrams, 2017). Potts and Crowther have carried out experimental investigation of aerodynamics in a wind-tunnel.

In order to improve its range, an inventor found the reference of ancient Indian weapon and designed the product in a ring shape with asymmetric curved top (Adler, 1985). Since 1970 Adler started designing, developing and manufacturing the ring. Now it is sold by the name Aerobie. It is made up of polycarbonate core. Core is covered by rubber from both inner and outer peripheries. A spoiler kind of shape is given to the outer side, which gives it level flight.

Conclusion

The historical weapon *chakra* has motivated people to improve to modern day toy. As a weapon also, its importance is enhanced in closed combat when used by a skilled soldier. Scientific and technological design ideas are available in the ancient Indian texts. Even those ancient scriptures, which are termed in present era as a work of fiction, has a value, which is of motivating and inspiring present generation to build things, and understand the science behind it, using modern day tools of visualisation, computation and manufacturing. Not only the history of ancient Indian ring weapon is fascinating and its modern day versions are popular among children and youth as a sport but also its pedagogical significance lies in the fact that it can be used to demonstrate rotational motion of a rigid body. Students should appreciate the science behind the disc and ring-throwing sport, just as they enjoy learning about the toy top.

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