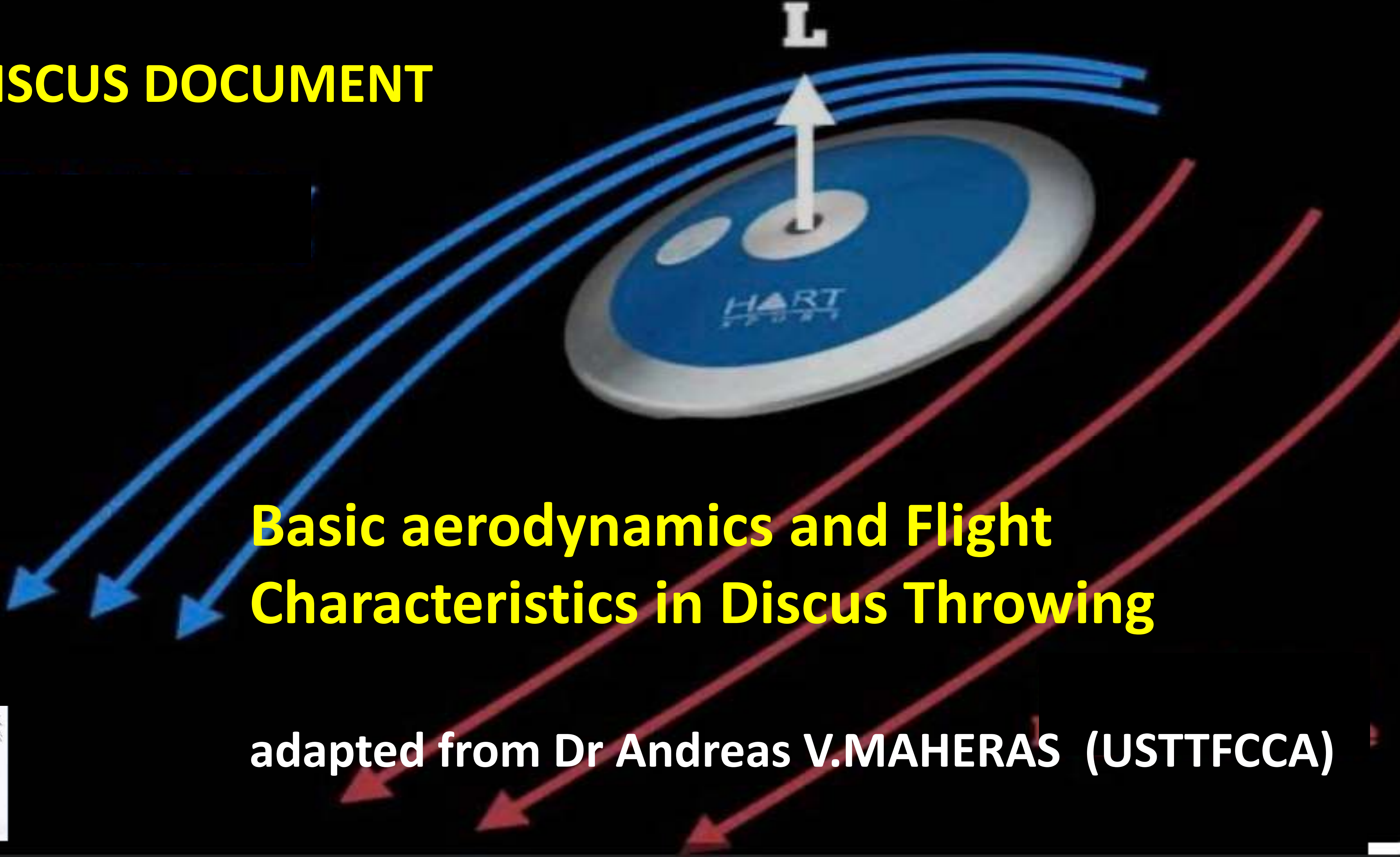
DISCUS DOCUMENT



Basic aerodynamics and Flight Characteristics in Discus Throwing

adapted from Dr Andreas V.MAHERAS (USTTFCCA)

DISCUS DOCUMENT
DLP THROWS COACHING

The discus is an extremely aerodynamic implement (Hubbard, 2000). This implies that, under certain conditions, the distance thrown can be increased or decreased significantly beyond or below to that expected in a vacuum or in still air. A notable example is from the men's discus final during the 1976 Olympic Games, where the gold medalist released his discus a significant 1.4 m/sec., less than the silver medalist (25.88 m/sec. vs. 27.28 m/sec., Terauds, 1978).

However, aerodynamic factors dramatically affected the distance achieved by those two throwers. In a vacuum, the same author calculated that the silver medalist would have thrown 4.06 meters further than the winner. Indeed, the aerodynamic forces acting on the discus during its flight can decisively alter the course of its trajectory positively or negatively.

So much so that the first author to publish scientific data regarding the effects of wind on the discus Taylor (1932) suggested that it would be unfair to allow records achieved under favorable conditions.

Dr Andreas
V.MAHERAS

DISCUS DOCUMENT

DLP THROWS COACHING

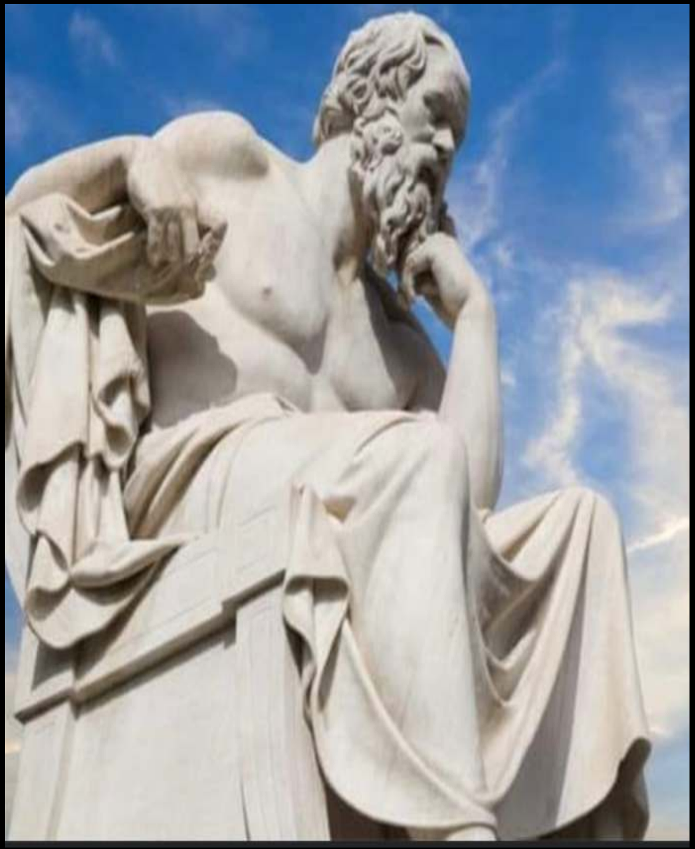
Those favorable conditions are created as a result of fluctuations in the relative wind speed, primarily, and secondarily, the angle of release, the velocity of release, the attack angle, the inclination angle, the tilt angle, the rotation of the discus around its short and long axes, the effective mass of the discus and, its moment of inertia.

During its flight the discus is influenced by gravity and the aerodynamic forces of lift, drag and pitching moment. Those forces act on the center of pressure (CP) which does not necessarily coincide with the center of gravity (CG) of the discus and is located somewhere in front of the CG. Drag is the product of the dynamic pressure (pressure in the front of the implement is greater than that in the rear), the cross-sectional area and a dimensionless drag coefficient.

The other component, lift, is the product of the same elements but with its own dimensionless coefficient which measures the effectiveness of the implement to produce force perpendicular to the velocity vector.

Those two coefficients along with the pitching moment coefficient depend on the attack angle. The angles of interest that are formed during the launch of the discus are those of release, attack, inclination, tilt, along with the pitching moment.

LIFT GENERATION



The typical theory to explain how lift is produced, is with the use of the Bernoulli principle which states, there is a high air speed and low pressure on the top of the air foil (wing-discus-frisbee etc.) and a low speed and high pressure on the lower surface of the foil.

The difference in pressure creates a positive, upward lift. However, this theory has been challenged as trivial, incorrect or incomplete (NASA). That is, it does not explain why the velocity is higher on top, and so the explanation of lift presented is no real explanation, or more precisely it is a trivial truism (Johnson & Jansson, 2015).

Other theories that have been proposed include the Newton's third law theory, the "longer path" theory, the "downwash" theory, the Coanda effect theory, the Kutta-Zhukosky lift theory and the Prandtl Drag Theory. According to Johnson & Jansson (2015) none of these theories present a correct explanation of flight. They postulated that the aforementioned theories can be classified according to three conditions: trivial and correct, trivial and incorrect and, nontrivial but incorrect.

They suggested that what is needed is a nontrivial correct theory and he offered a combination of the Bernoulli's principle and Newtonian physics theory as an explanation of how lift is generated. The detailed description of any of those theories is beyond the scope of this narrative.

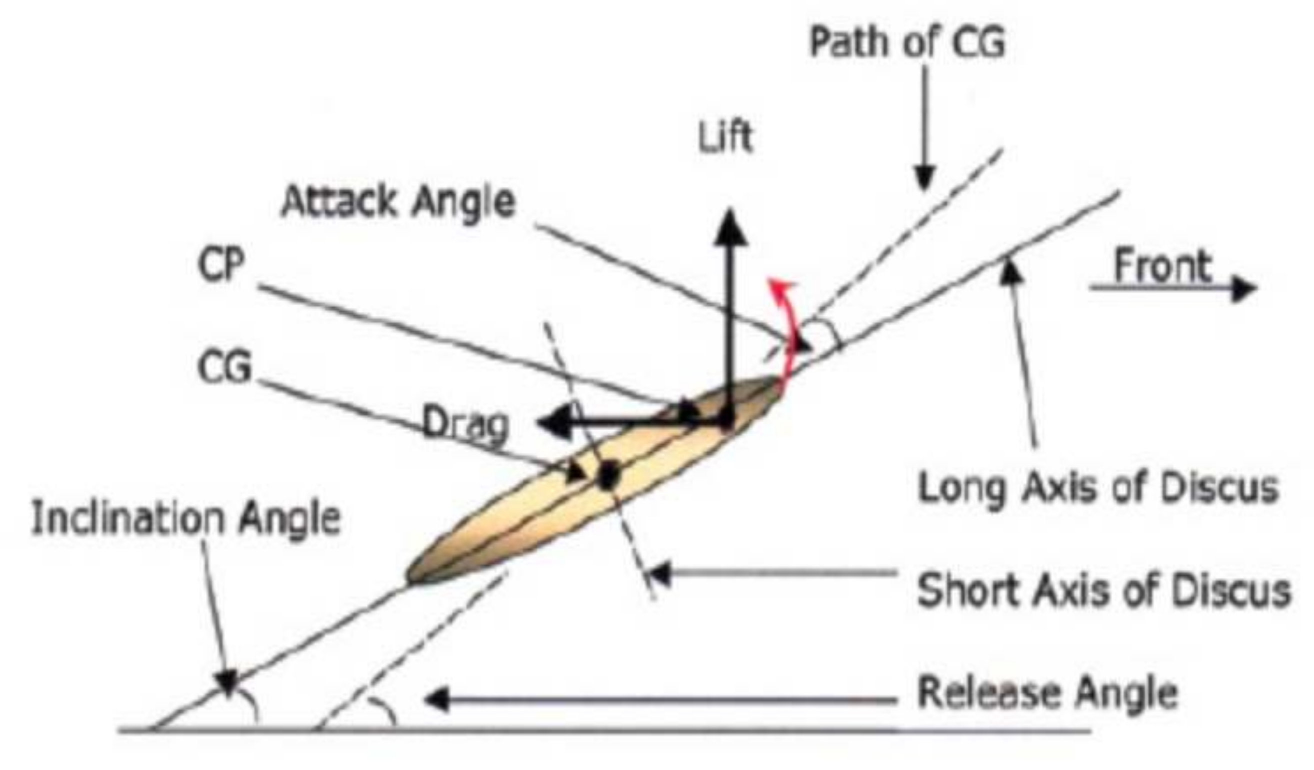
ATTACK ANGLE

The optimum angle of attack of the discus depends on the angle of release. A negative angle of attack means that the initial direction of the center of gravity points upwards in relation to the long axis of the discus (figure 1), with the opposite being true for a positive attack angle.

Negative attack angles are the predominant in high level throwing.

Generally, the negative angle of attack should increase as the angle of release increases and decrease as the angle of release decreases. At an approximate release angle of 25 degrees, the angle of attack is at zero (Terauds, 1978). In still air, the optimized attack angle will be at -4 to -10 degrees (Soong, 1976; Frohlich, 1981; Hubbard & Cheng, 2007).

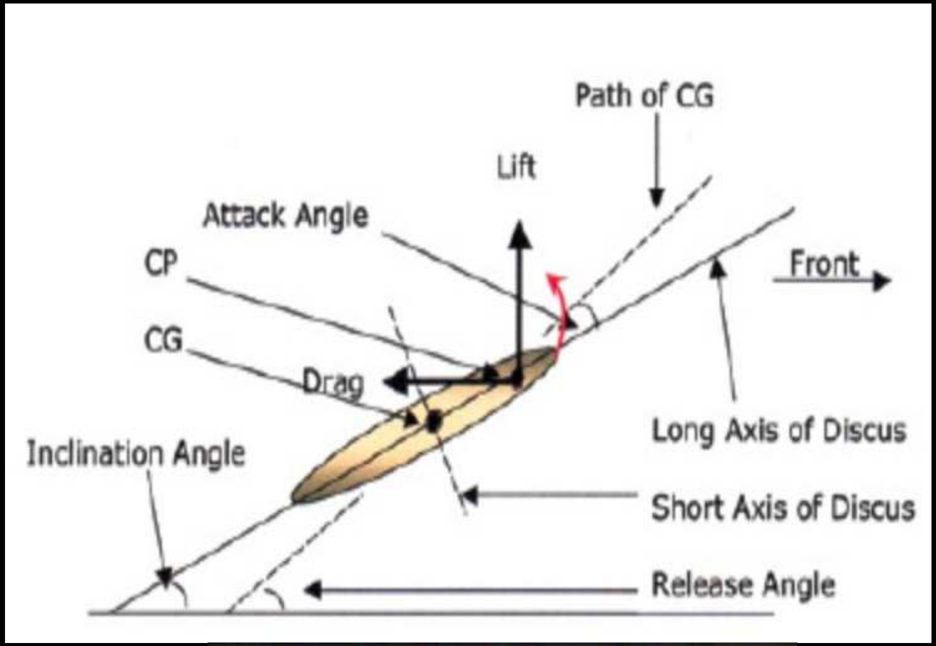
Along with other release parameters, Chiu (2008), also calculated a -10.25° angle of attack as optimal for breaking the current men's world record, and that of -9.25° for breaking the current women's world record



The magnitude of the lift, drag and pitching forces will strongly depend on the attack angle (figure 2). According to Seo (2013), Seo et al. (2012) and Ganslen (1964), lift increases linearly with the angle of attack up to the stalling angle which is at 30°. At that point the discus experiences a sudden decrease in lift and at 90° the lift force is zero.

The drag force also increases with increasing attack angle from 0° to 90°. Ganslen (1964) showed that the sudden decrease in lift at 30° also coincides with the formation of a "turbulent wake" behind the discus. Discus performance will be improved if the discus has a relatively flat angle of attack.

Once the discus develops an angle of attack to the relative wind, it will continue to exaggerate the "nose up" tendency which is termed as a positive pitching moment. This implies that a flight path initiated near the point of the stall angle for the discus, it will necessarily result in a stalled discus with high drag and low lift. Therefore, an optimum attack angle will allow the discus to complete its flight without stalling.



A term that has been used in reference to the attack angle, is the maximum lift/drag ratio and more specifically the attack angle at which that maximum ratio occurs. Taylor (1932) and Ganslen (1964) found that the maximum value of the ratio occurred at an attack angle of 9°. This value seems to be in conflict with a generally accepted negative optimal angle of attack.

DISCUS DOCUMENT

DLP THROWS COACHING

. Hay (1985) attributed this discrepancy to the ever changing angle of attack during the discus's flight speculating that the optimum angle obtained at release will be the one that would yield the best results overall and not at a particular instant in flight.

On the other hand Hubbard (1989) mentioned that the lift/drag ratio is a concept used in aircraft design to resolve issues related to the maximization of the steady cruising range of an aircraft.

He stated that this ratio is irrelevant in a discussion of the transient behavior of a discus and that, as an aerodynamic term, it should disappear from the discus literatur

RELEASE ANGLE, ANGLE OF TILT, INCLINATION ANGLE

Terauds (1978) reported that the angle of tilt at release should be at 15° which he probably estimated from field or film observations. Soong (1976), found that with reasonable initial discus rotation, the release angle and the angle of inclination have a large effect on the range.

At zero wind, the optimum combination of release angle and inclination angle is 35°/26° respectively if they vary independently. If they vary together, that optimum is at 33°. However, the former ratio will result in a 1.55 meters gain in range.

Frohlich (1981) agreed that the optimum strategy in still air is to release the discus so that the inclination angle is about 5 to 10° less than the release angle. Although this results in negative lift during the early stages of the flight, it allows for a minimum of drag and optimum average lift throughout the upward part of the discus flight.

Results from optimization studies that assumed a 0° angle of tilt, indicate that for elite throwers the discus should be thrown at release angles between 35-37°, inclination angles of 26-27°, and attack angles between -9 and -10°.

Slightly higher release angles and more negative angles may be more suitable for throwers capable of lesser release speeds. Voigt (1972) claimed that by modifying his data to account for a -17° tilt angle at release, the range will improve by 2.7 meters.

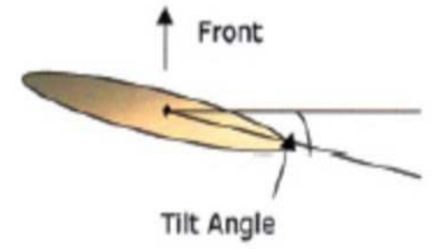


Figure 1. Aerodynamic forces and angles during the discus flight. Top: view from the side, bottom: view from the back. Red arrow depicts the pitching moment. CG=Center of Gravity, CP=Center of Pressure.

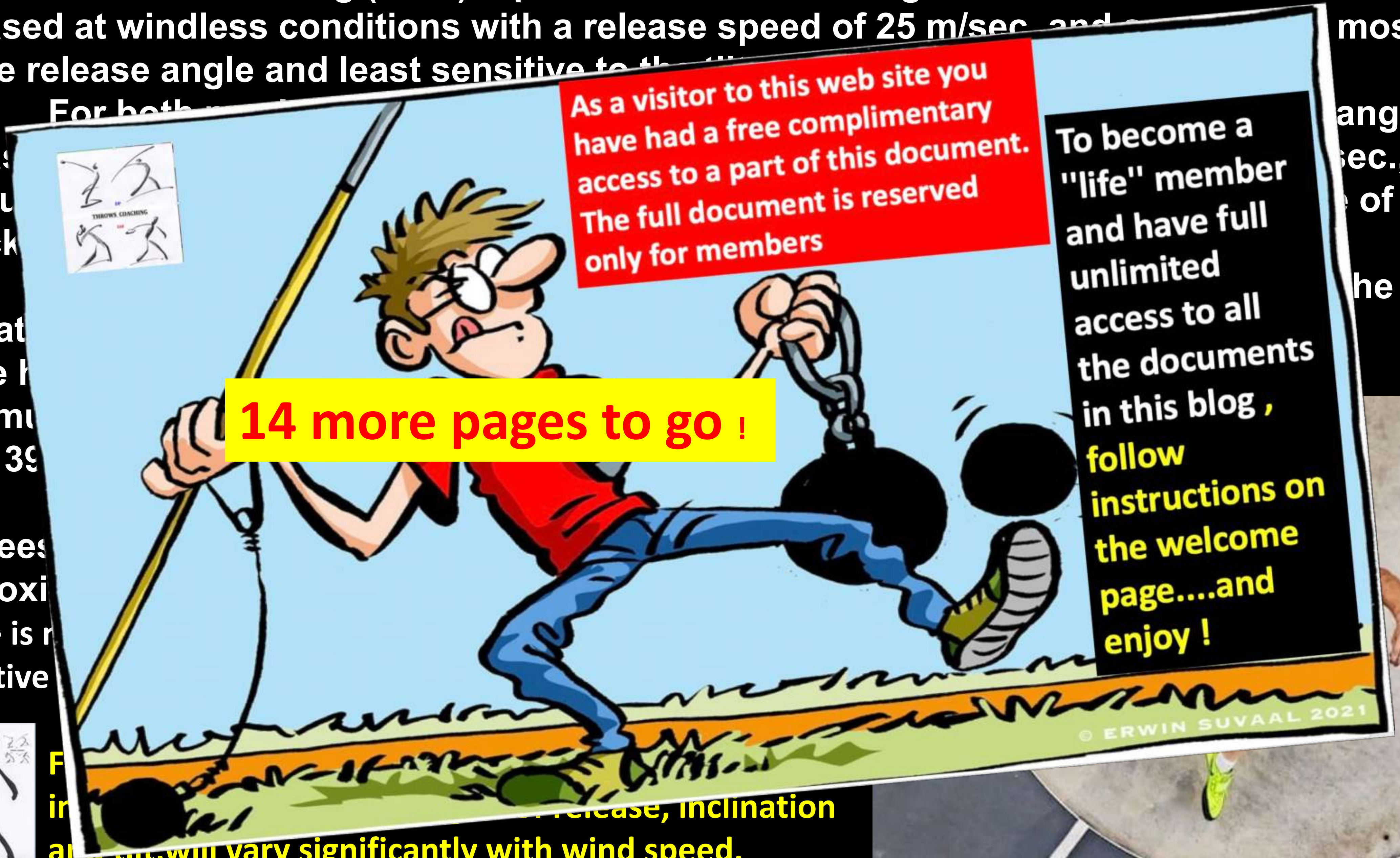
Hubbard & Cheng (2007) reported a maximum range of 69.39 meters with a men's discus released at windless conditions with a release speed of 25 m/sec, and ... most sensitive to the release angle and least sensitive ...

For both ... angles of releas... sec., is produ... of 54.4° and attack...

... the other

Deviat... while ... minimu... than 39...

degrees... approxi... range is ... sensitive ...



F... in... release, inclination an... tilt, will vary significantly with wind speed.

DR. ANDREAS MAHERAS

TITLE: Assistant Track and Field Coach (Throws)

EMAIL: avmaheras@fhsu.edu

DISCUS DOCUMENT

DLP THROWS COACHING