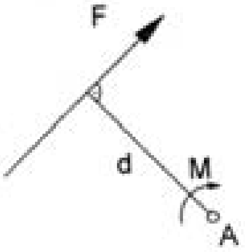
THE FUNDAMENTALS OF STYLE

By Vladimir Milosavljevic

ALTHOUGH VERY SIMPLE IN MANEUVERING DESCRIPTION, CLASSIC STYLE SKYDIVING HAS VERY INTERESTING HISTORY AND A STORY THAT IS STILL NOT OVER.
TO UNDERSTAND BETTER WHAT IS GOING ON IN STYLE PERFORMANCE AND WHAT TENDENCY STYLE JUMPING WILL HAVE IN THE FUTURE, I WILL PRESENT SOME ANALYSIS THAT WILL INCLUDE MECHANIC AND AERODYNAMIC FACTORS, NECESSARY TO EXPLAIN FUNDAMENTS OF STYLE JUMPING MANEUVERS. IN THESE EXPLANATIONS, SOME SIMPLIFYING WILL BE USED I.E. NEGLECTING THE FACTORS THAT DO NOT PLAY AN IMPORTANT ROLE.

Turns

Freefall turn is defined as a relative angular movement around some vertical axis. In accordance with Newton's First Law of Motion, a turn must be initiated by the moment and stopped by the moment in opposite direction.



In skydiving, a moment could be defined as an action that can set our body into a rotational maneuver. It could be created by forces in couple, or by some eccentric aerodynamic force. Here, eccentric aerodynamic force is a resultant aerodynamic force that is not in line with body's center of gravity. By the way, if this resultant aerodynamic force passes through skydiver's center of gravity, then a force is concentric and a skydiver's body will stay in equilibrium or go into translation.

The intensity of the moment, or it's ability to create rotation around some axis, is equal to the product of the intensity of the force and the shortest distance from the force vector to the axis (A). We can mathematically write it like this...

M=F*d

where M is the moment, F is the force and d is the shortest distance from the force vector to the axis. This means that a moment is greater if we either increase the force or the distance from the force vector to the observed axis, or both.

In skydiving, we can regulate the distance of the force vector from the observed axis by changing the distance of the control surfaces from the axis of rotation. The greater the distance, the greater the moment. That's why in style, some jumpers start their performance wide, allowing them to increase this steering moment. However, this action has also some other effects which we will discuss later. Now, let's look at the fundament of the aerodynamic force of drag itself... It consists of several factors:

F = Cx * __v^2 * A

Where F is the force, Cx – coefficient of drag, _ is air density, v is freefall velocity and A is area exposed to the relative wind. Assuming that an air density _ has a constant value, these factors explain that in skydiving in general, jumpers increase their steering force by:

1) increasing their freefall velocity
2) Increasing the area of their control surfaces exposed to the relative wind, and
3) increasing the coefficient of drag on their control surfaces.

In style, jumpers increase their freefall velocity in a long dive before starting their performance. They increase the area of their control surfaces by wearing large gloves and they increase the coefficient of drag by cupping their palms in maneuvering. Now, to understand more fundaments of the turn, let's become familiar with Newton's Second Law of Motion.

Newton's Second Law of Motion

In rotations, Newton's Second Law of Motion defines a relationship between the moment, rotational inertia and angular acceleration.

M=I*a

Angular acceleration is defined as the rate of increasing or decreasing the angular speed. The angular acceleration is bigger if we change our angular speed more rapidly. In style turns, we need the biggest angular acceleration possible because that provides fastest start and fastest stop. OK, but how to achieve this?

Let's analyze Newton's formula again:

M=I*a

M is the moment, I is the rotational inertia and a is the angular acceleration. We can solve this formula for angular acceleration and we get:

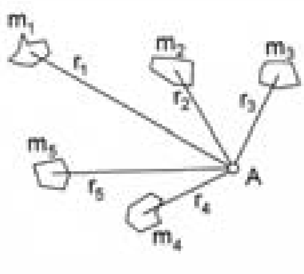
a=M/I

Here, we see that the angular acceleration depends on the moment and rotational inertia. That's the moment divided by the rotational inertia. This means, we will get the biggest angular acceleration if we increase the moment as much as possible and decrease the rotational inertia as much as possible.

Few steps earlier, we defined a moment; how to increase it and how to decrease it. Now we need to explain a term "rotational inertia".

Rotational Inertia

Rotational inertia is a characteristic of the body that resists angular acceleration. This resistance is caused by body mass and the positioning of that body mass in relation to the axis of rotation.



Basically, the following picture and formula explains how this fundamentally works:

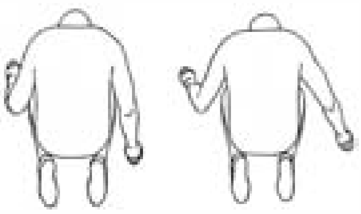
I=S(m*r^2)

Where I is rotational inertia, m is body mass, and r is radius.

The Rotational Inertia of the body is the sum of all the masses of the body, each multiplied by the square of their distance from the axis of rotation (A).

Classic Style Skydiving

This shows that the larger the masses and the farther away they are from the axis of rotation, the greater the rotational inertia. …and vice versa, the smaller the masses and the closer they are to the axis of rotation, the smaller the rotational inertia.



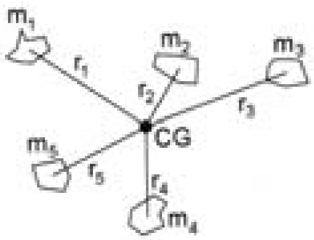
Now, here in style, we have a scientific conflict! Earlier we said that we have a greater steering moment if we increase the distance of the control surface from the axis of rotation, means to fly wide, and we just implied that we should fly narrow to decrease our rotational inertia. So, then, when flying in the style tuck position with our hands wide, which has more influence? Increased steering moment? …or the increased rotational inertia?

In accordance with my calculations, if the steering is done correctly, the steering moment has a greater influence, telling us that style jumpers should fly wide.

It is true that rotational inertia changes more rapidly by changing the distance because it depends to the square of the distance. However, flying wide or flying narrow in the style tuck position, considers only moving the arms: away or towards the axis of rotation, which is actually moving of only about 10% of our total body mass. This does not produce significant impact on rotational inertia of our body, while at the same time it produces directly proportional change in the intensity of our steering moment. This means, when flying wide, our increased steering moment has greater influence, and is overcoming our slightly increased rotational inertia!

Now, let's review another magical thing… If we look more closely at the equation for rotational inertia,

$$I=S(m*r^2)$$

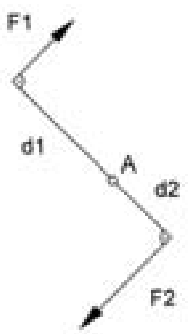


we can notice that, for the same body, this sum is the smallest if we measure those distances (r) from some CG axis. That means, that among all the parallel axes of rotation, the rotational inertia is the smallest for CG axis. This practically means that, for the same rotational input on the same body configuration, the rotation is the fastest if a body rotates around it's CG!

CG rotation

To rotate around the axis that is passing through our center of gravity, we must apply forces in couple that will satisfy the following equation:

$$F1*d1=F2*d2$$



where F is a force, d is the shortest distance from the force vector to the axis (A), 1 and 2 are references, like for the hands, 1 is reference for the left hand and 2 is a reference for the right hand.

Also, the straight line that connects the points of force application, i.e., our forehands, must pass through our body's CG. This is very important because, although the forces could be in couple, those will never give CG rotation if this rule is not satisfied.

Usually, with proper commanding, steering forces in style turns are equal, so the distances should be also equal. Here we can conclude that in style performance, we should actually apply our forearms so that one pulls forward, another one – backward, symmetrically to our CG.

Any other force application will produce some eccentric force situation and additional adjustments to the commanding will be necessary. This, however, eats fragments of seconds of our performance time and is not desirable at all.

Basic body position

By defining the proper way of maneuvering in style turns, we can also define our basic, steady balancing, body position from which we start and stop efficient maneuvers with minimal body movements. Assuming that most sportsmen have some standard moving capabilities, minimal body movements in commanding provide saving of our performance time as well.

For this purpose, a proper basic tucked position would be with palms of our hands positioned symmetrically and on the opposite sides of CG, so that imaginary straight line passes through both our palms and CG. This position will enable same path of both hands in commanding action which implies minimum amount of performance time as well.

Here, it is very important to notice that, in order to have these elements on it's proper place, we must be tucked properly, so that our CG does not go too much forward or too much aft.

Also, usually after performing a loop, advanced style jumpers are starting another turn from more head-down position; however, even then, all these mentioned elements must be kept in order to continue flying with maximum efficiency. …hands on the opposite side of CG, same commanding action etc.

Stability

From the standing point of theory of Skydiving Stability (fundaments of physical laws of skydiving stability are explained in a great depth in instructional DVD "Body Pilot in Command"), the fastest maneuverability in style will be achieved if we fly in an unstable body position. Instability provides faster response to our initial commanding and faster relative maneuvering itself. An unstable position is basically any position in which center of pressure (hanging point) is below the center of gravity and it could be easily recognized as a concave surface exposed to the relative wind.

With this additional knowledge, we can still affirm that the most suitable and most effective unstable basic body position is a style tuck. This position provides a high level of instability, minimal movements in commanding and almost minimal rotational inertia around vertical and pitch axis.

On the other side, flying in this position requires skill to remain balanced on the top of the bubble of air, but we must have in mind that we will never be able to maneuver fast if we don't use this or eventually other unstable body position. Style jumpers should fly as unstable as they can handle without tumbling over onto their back!

Loops

A loop will go fast if we decrease our stability as much as possible, decrease our rotational inertia around pitch axis as much as possible, and present a stronger looping moment. Generally, a loop starts when we apply the initial moment to an unstable body position and a loop stops when we apply sufficient moment in the opposite direction.

Initiating a loop from a style tuck position is relatively easy because we already exist in an unstable body position. So here, we should rather speak of most effective technique that will provide a fast start, fast stop and relatively easy coordination during the entire loop.

Many of various techniques for achieving this have various pros and cons. I choose to introduce you to the technique employed by true master of this discipline, Cheryl Stearns.

A loop starts from an unstable position, with forearms slightly forward and lowered. This way Cheryl further decreases her stability and produces the eccentric force i.e. a moment to start rotation. Here, there are no forces in couple that would create a perfect loop (CG rotation) because the only force producer, wind, is coming from the ground, but, there is initiating a loop from one side and stopping on the other, which is excellent for preventing of back sliding and excellent approximation of force couple.

After initial commanding, Cheryl rotates around her pitch axis while keeping her forearms perpendicular to the relative wind to maintain the maximum pitch moment. Once her thighs are parallel with forearms, she becomes rigid in elbows too, joining her forearms to the rotation action of the rest of the body. Finally, once she feels the air on the opposite side of her fists, she twists her forearms, facing her palms into the relative wind to stop rotation. Soon after arms, her legs are joining this stopping action too.

By using this technique, Cheryl stops a loop just at the starting style tuck position, with no backslide, no overshoot nor further oscillations, allowing immediate start of another turn. Also, by using this technique, she rotates almost exactly around the CG which gives her excellent time in loops.

Additional masses

In accordance with theory I explained earlier, we can conclude that every additional mass attached to our body can change our balancing situation and produce unwanted effects. Our rig, as a major additional mass must be placed in manner so that we, fully equipped, have the balancing picture described in previous sections. Proper tucking here plays an important role. But also, if, for some reason, we can't get our desired elements in any tucked position, we should add extra weights on some end in order to put our CG on its proper place.

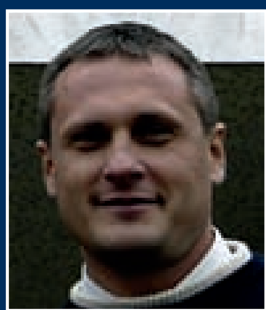
Once we have everything set, every other eventual additional masses attached to our body should be as small in size as possible, as close to our CG as possible and well secured. That way, the rotational inertia of these additional items will be kept to a minimum.

Final

As we said in the beginning, although very simple in the initial description of maneuvers, four turns and two loops, classic style is a very complex skydiving discipline that requires a lot of skill, theoretical knowledge and practice. To become a good style jumper, you must be able to make good compromise between scientific requirements and your personal qualities.

Vladimir Milosavljevic assisted by Tamara Koyn
Photos: Sean Capogreco, style jumper Cheryl Stearns
technical & body position drawings by Vladimir Milosavljevic

About the Author



__Vladimir Milosavljevic__ (38) graduated on Faculty of Mechanical Engineering, group for aeronautics, in Belgrade (Serbia) in 1997. He attended Bourland Flight Academy in Fort Worth TX, USA and got his CPL from FAA in 1999. Together with US freestylist Tamara Koyn in 2000 he published an article "Skydiving Stability" based on his scientific research about relationship between stability and maneuverability in skydiving. In 2002. Vladimir and Tamara issued instructional DVD "Body Pilot in Command" that refer to all skydiving disciplines. Same year, 2002, Vladimir promoted his invention Vladiball www.vladiball.org (World's first safe skyball), after final tests in Skydive Arizona.

__Tamara Koyn__ has pioneered freestyle since 1985, world champion in 1992 and is currently a FAI rated judge in both Artistic Events and Formation Skydiving. http://www.koyn.com/CloudDancer