# Wingsuit Design Technology in the Framework of Functional Requirements

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## Abstract
As always, everything in our lives is subject to change and rapid development. If I told you that you can fly in the air as you wish like a bird, you would not believe me, but it is the truth. With scientific research and technological applications, a trained person can now do that with a risk ratio, that’s why this sport is classified under what it is called extreme sports, but what we are working on now is laying the scientific foundations and using modern technological applications and advanced textiles that put the wingsuit in another level of safety and ease of use; Do you worry about flying squirrel from falling!!

This research deals with all aspects involved in designing the wingsuit in terms starting from the physical technique of flying the suit, which is based on aerodynamics; And theories responsible for flying aircraft and its gliding, to the various functional designs of the suit and the textiles used in manufacture. The research also includes aspects of technology used in testing and manufacturing.

Accordingly, it is considered the cornerstone in Egypt and the Middle East for such functional clothing that can contribute creating a boom in the sport and military field, also it paves the way for researchers to enter this area, which rarely finds anyone who offers to work on it because it contains many specialized scientific branches that must be merged to produce this product “wingsuit”.

## Keywords*:*
Wingsuit, Aerodynamic, Technology, Function, Textile.

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## Introduction:

From the very beginning of humanity, man have great passion and desire to fly; it was very clear through many fatal trials and drawings. Through decades men never stop dreaming to fly and have wings. So recently we can find many types of extreme sky sport, no matter what type of skydiving sport you practice if you can fly like a bird in the sky. The most likely flying method that looks like a bird is flying with wingsuit, pilot can control his flight by changing his body poster. The human body becomes aircraft.

Over the last century, the evolution of human flying is strongly tied to the technical improvements that happened in parachute. Each major advancement in equipment led to huge change in the skydiving sport.

Wingsuit is a garment that enables a person to fly when in free fall. The suit has some sections between the legs and arms; these sections inflate when the pilot jumps from a high place (Kalayci, Avinc and Yavas 2016)

Wingsuit flight and design stills in the pioneering stages and all the current developments of wingsuits regarding aerodynamics are naive. Since the first successful commercial wingsuits the design changed to improve and use ram-air inflated to form airfoil-shapes. Current wingsuit designs are very similar for all manufacturers. Application of the principles of aerodynamic and scientific development of new designs appears to be rare. (Sestak 2017)

**Research Problem** is focused on Egypt's lack of a winged flight suit despite the modern technological development in the field of free flight and its availability in other countries, ,,,,, which makes presenting an accurate study on the requirements for designing, building and producing this type of suit to perform the required function of it is considered as laying the foundations Technological and scientific opportunities that open the way for the creative future of this industry in Egypt.

**Research Objective** study the design and functional requirements of the wingsuit through the scientific and technological foundations that enable it to perform the required function, whether military or sports, with more accurate results while reducing expected risks.

**Research Importance** is to introduce the importance of wingsuits to the local market as a worldwide product that can be manufactured in our country including the following sectors:

- **Scientific importance** represented in establishing scientific bases for a strategic product in the field of functional clothing for the first time in Egypt.
- **Strategic importance** lies in its three areas of usage (sports, police, and military) military usage in the rough places like Saini to help soldiers reach those unreachable areas safely and easily, sport usage brings economic return because the nature of the surface and the weather in Egypt is suitable for practicing this type of sport, also it will help in tourist attraction.

## Research Limits:

The research is limited to studying the technology of designing a wingsuit through various scientific sources that have recently been written about, whether scientific letters and periodicals, academic books or data and information from the international information network (the Internet) in the English language.

**Research Terms:**

- **Wingsuit:** a jumpsuit worn by a skydiver or BASE jumper with folds of fabric between the arms and legs that create lift when extended and allow the wearer to glide through the air over long distances.
- **Aerodynamic:** a branch of dynamics that deals with the motion of air and other gaseous fluids and with the forces acting on bodies in motion relative to such fluids.
- **Technology:** the application of scientific knowledge for practical purposes, especially in industry; dealing with engineering or applied sciences.
- **Function:** is a relation between a set of inputs (called the domain) and a permissible set of outputs (called the co domain), such that each input is related to exactly one output.
- **Textile:** any filament, fiber, or yarn that can be made into fabric or cloth, and the resulting material itself.

## 1. Fundamentals of aerodynamics

A right understanding of the physics behind gliding allows you to improve wingsuit designs that tailored to individuals. Different wingsuit designs should suit people of different weight, size, and expert. Figure 1(Landell-Mills 2021)

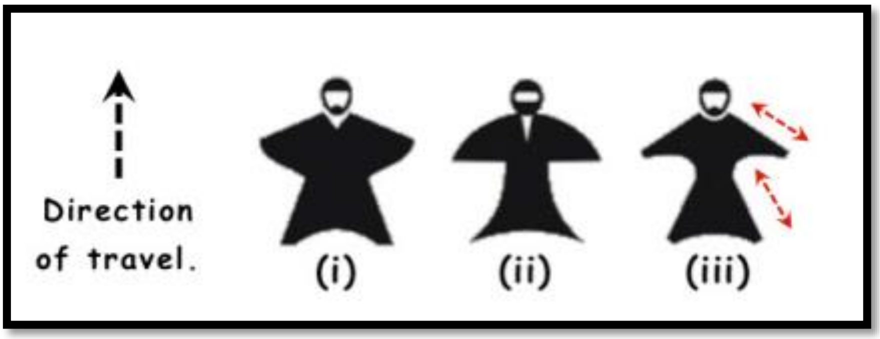


FIGURE 1DIFFERENT WINGSUIT DESIGNS

The aerodynamics basic concepts are simple. Lift makes you go up. Weight makes you go down. Thrust propels you forward. Drag resists forward motion. But when it come to a heavy object especially without much of a wingspan fly through air is much more complicated. (Ferguson 2016)

Based on Newtonian mechanics according to the mass flow rate, physics of how animals and objects glide is the same. For example, squirrels and wingsuits generate sufficient lift to glide through air it pushes the air flow through downwards. Altitude is traded for forward airspeed and lift. Squirrels and wingsuits are characterized by low aspect ratios and a steep descent at high speed. Figure (Landell-Mills 2021)

**FIGURE 2: FLYING SQUIRREL AND, WINGSUIT**

Lift and drag forces both are the components of resulting aerodynamic force that affect the flying body, either perpendicular or in parallel to the stream velocity with the lift to drag ratio which form one of the key parameters for aerodynamic efficiency. Figure (Ansari, Krzywinski and Fröhlich, Towards a Combined CAD and CFD Development 2018)

The movement resulted of the wing through stationary air form a lift force perpendicularly to the motion of the wing, which is greater than the downwards gravitational force affects the wing which keeps the aircraft airborne. The lift accompanied by dragging represents the air resistance against the wing as it passes through the air. The drag depends on the area of the wing directly facing the airflow as well as the form shape of the aerofoil.

The magnitudes of the lift and drag depend on the **angle of attack** between the direction motion of the wing through the air and its chord line. (Electropedia 2021)

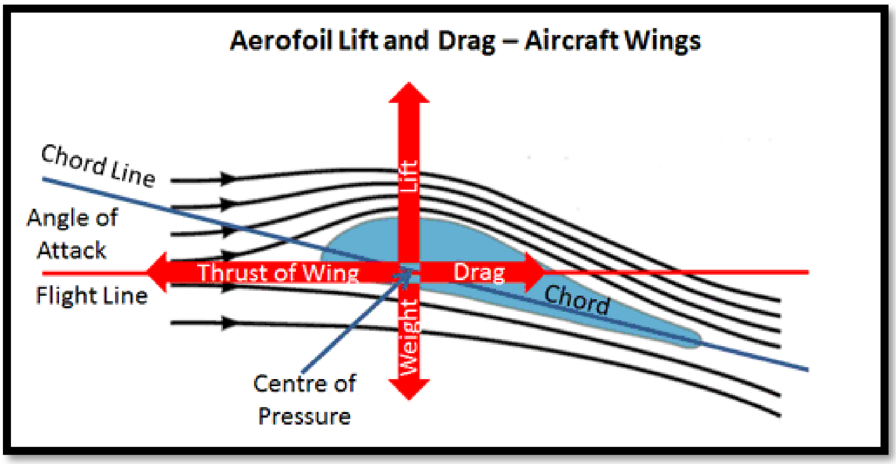


**FIGURE 3: AIRCRAFT ARE KEPT IN THE AIR BY THE FORWARD THRUST OF THE WINGS OR AEROFOILS, THROUGH THE AIR. THE THRUST DRIVING THE WING FORWARD IS PROVIDED BY AN EXTERNAL SOURCE, IN THIS CASE BY PROPELLERS OR JET ENGINES.**

## 2. Aerodynamic flying wingsuit

Anybody passing through air will produce an aerodynamic force. This force is called (the total aerodynamic force) or the resultant aerodynamic force (R). The aerodynamic force can be represented by the force of lift (L), which is generated perpendicularly to the relative wind or the direction of travel; and drag (D), is the resultant force opposite to the travel direction and parallel to the relative wind. Weight (W) represent the acceleration of the aircraft mass (m) by the gravity force (g), thus W = mg. (Anderson 2005)

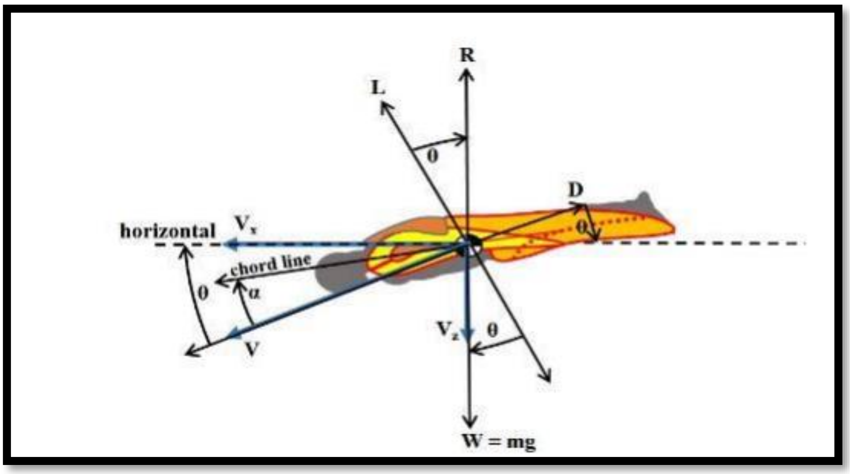


**FIGURE 4: DIAGRAM OF THE FORCE VECTORS AND VELOCITIES GENERATED BY A WINGSUIT IN FLIGHT. FORCE VECTORS ARE SHOWN IN BLACK, AND VELOCITIES ARE SHOWN IN BLUE.**

For the purposes of analyzing, lift and drag, which are developed by the wings of both arms and legs, can simplify as single force acting passes through the center of gravity. The force balance is generated by the different parts of the wingsuit is very important for both stability and glide performance. (Sestak 2017)

The difference between aerofoil aerodynamics and wingsuit aerodynamics is that the latter is a 3D wing with finite aspect ratio AR. The space between the skydiver's hand and legs is utilized for making the wing segments using a particular shape of a selected aerofoil. The basic wing theory involved in wingsuit aerodynamics is the skydiver on jumping from the aero-platform or a platform i.e., airplane or cliff etc., dives into the air and the wingsuits makes use of the ram air and takes the shape of the aerofoil. (Chandra and Tripathi 2021)

## 3. Designing the Wingsuit

Wingsuit must be built very carefully like other sky sports equipment because of the potentially high-risk existence that could lead to death. It is very important to consider choosing the appropriate material and aerodynamic forces on manufactured the wearable garment during flight. Although wingsuit has many names such as "birdman suit", "flying squirrel suits" and "skydiver suit", but "wingsuit" is the most popular name. This suit has a lot of research background. Although, the different types of wingsuits that are available, there are many research that aim to improve wingsuits performance. (Kalayci, Avinc and Yavas 2016, Kalayci, Avinc and Yavas 2016)

Matt Gerdes, the modern wingsuit company "Squirrel" founder explains "as [wingsuits] have increased in surface area, we have made steps forward in reducing drag and increasing efficiency" (Kelsay, Development of Human Body Flight 2016)

**Figure 5: Late 1990s "Bird-Man" brand wingsuit (left) versus modern "Squirrel" brand wingsuit (right)**

Squirrel made this improvement by inserting semi-rigid foam into the leading edges of the wingsuits and enlarges the air inlets to be more efficient and to allow the wingsuit to inflate quickly and assume a rigid airfoil shape that increases lift. They also added Mylar to the surfaces just above and below the leading edge of the suits to reduce drag and improve efficiency (Kelsay, Development of Human Body Flight 2016)

Aerodynamic profile improving of the leading edge of the wingsuits and increasing strength of that leading edge is often credited with improving wingsuit speed, which allow more lift and more control over altitude. (Borys 2015)

The wingsuit shape is maintained by the human body form wearing it and ram-air pressure in the hollow airfoil sections of the leg and arm wings. This ram-air pressure is delivered to the suit through the strategically positioned small inlets on the surface of the suit as shown in Figure. (Sestak 2017)

**Figure 6: A close-up detail of a stiffen reinforce wingsuit the ram-air inlet over monofilm laminate on a wingsuit of Squirrel brand (Squirrel 2017)**

**FIGURE 7: WINGSUIT INLETS ARE POSITIONED TO RECEIVE RAM-AIR TO PRESSURIZE THE AIRFOIL SHAPES OF THE SUIT. THEY CAN BE SEEN UNDER THE ARMPITS AND BETWEEN THE LEGS OF THE WINGSUIT SHOWN BY RED ARROWS ABOVE (TONYSUITS 2010)**

## 4. Textiles used in current wingsuit

Textile materials are commonly used in different sport garments and equipment. These textiles are known as sport technical textiles (sportech). Sport textiles' products are generally manufactured with high technology and/or specialized fibers such as high-performance fibers. At this point, some sport types such as extreme sports differ from others due to higher risk and danger probability. Especially, extreme sky sports may be accepted as one of the most dangerous sports and their most components contain textile materials importance for this specific field. (Kalayci, Avinc and Yavas 2016)

Modern wingsuits use state-of-the-art textiles and ram-air inflated airfoil shapes to create lift for gliding flight. Modern textiles made of nylon; polyester, aramids, acrylics, polyurethanes, olefin, polylactide, polyvinyl chlorides, silicone, and carbon now provide an even wider variety of choices for construction of wingsuits (Horrocks and Anand 2000). These substances appear in a variety of woven fabrics and films such as Parapack, Ripstop, Oxford, ballistic, and sailcloth with a wide range of surface qualities and strength capabilities (McQuaid and Beesley 2005)

The choice of the suitable fabric for the manufacture of the wingsuit depends on many factors such as how expert the pilot is, speed, cut of the suit and distance.

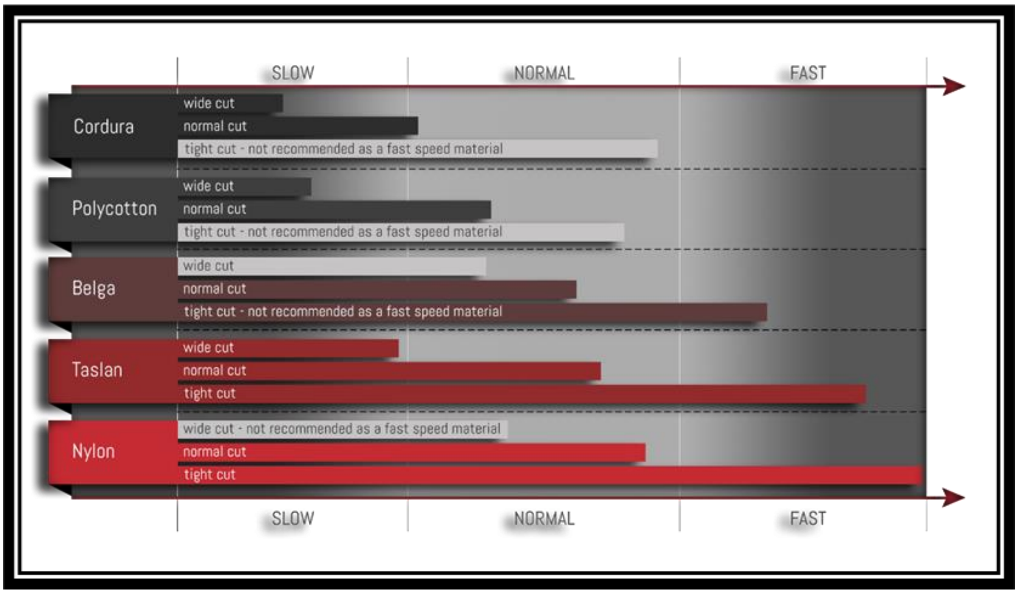


**FIGURE 8: MATERIALS BENEFITS CHART (INTRUDAIR N.D.)**

The composition of most containers is from either nylon duck (Para-pack) or Cordura®. Para-pack has a smooth somewhat shiny finish Figure; Cordura has a matte, more rugged appearance. Both are sturdy and long lasting. Most sport containers also utilize a thin foam lining on the inside of the flaps to smooth out the fabric and absorb wear and tear. Other fabrics, such as mesh, Spandex®, and ballistic fabric, serve specialized purposes. (Federal Aviation Administration 2015)

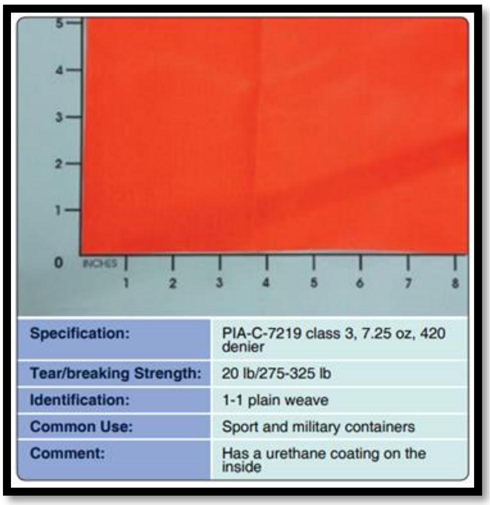


**FIGURE 9: CLOTH, DUCK, NYLON (PARA-PAK).**


| | |
|---|---|
| Specification: | MIL-C-43734, class 3 |
| Strength: | 1,000 denier |
| Identification: | N/A |
| Common Use: | Sport and military container systems |
| Comment: | Has a urethane coating on the inside |

**FIGURE 10: CLOTH, NYLON, CORDURA®.**

## 5. The different functional designs of wingsuit

Most modern wingsuits have the same basic features: flexible, durable fabric such as extra-sturdy nylon, air inlets and outlets, tougher leading edges, and various features for comfort and safety, such as reinforced booties and cut-away arms. The wings are designed to create an effective airfoil, although some companies emphasize this more than others. (Ferguson 2016)

### i.Wingsuit design for sport competition

Wing suit flight has evolved into a genuine sport recognized by the International Parachuting Commission (IPC) of the FédérationAéronautiqueInternationale (FAI) with international competition rules for performance flying (FAI Internnational Parachuting 2016).

The improvement in wingsuit performance along with the rising popularity of wing suiting within the skydiving community has led to the relatively recent development of wingsuit competitions. The first large-scale wingsuit competition was Red Bull Aces, a fourcross slalom wingsuit event which debut in 2014. (Kelsay, Development of Human Body Flight 2016)

FIGURE 11:RED BULL ACES ATHLETES COMPETING IN THE FOUR-CROSS SLALOM EVENT

Wing suit flight performance is measured in three competitive task areas: time, distance, and speed. Performance records are kept on the Paralog website which also explains the competition rules and procedures. These tasks are explained in Figure, Figure 13&Figure 14. The competition window is the airspace between 2,000 m and 3,000 m above ground level. The competitor exits an airplane between 3,500, to 4000 m above the ground and dives to the competition airspace. The competitor then tries to accomplish one of the three competitive tasks (paralog 2017).

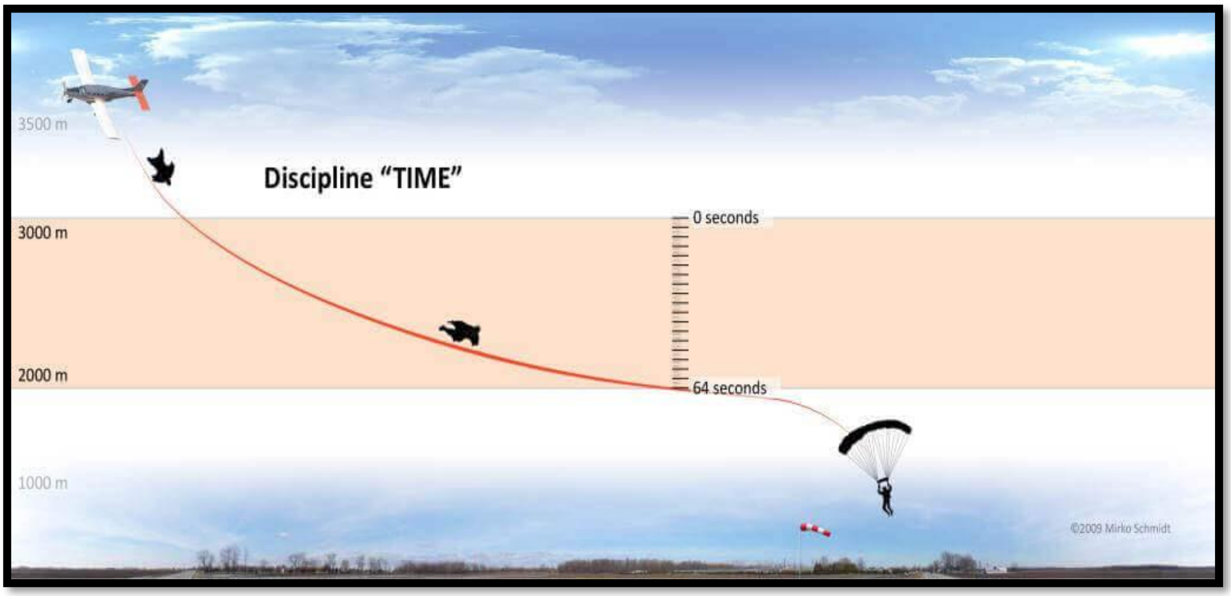


FIGURE 12TIME TASK: THE WINGSUIT FLYER IS TO FLY WITH THE SLOWEST FALL RATE POSSIBLE THROUGH THE COMPETITION WINDOW. THE RESULT FOR THIS TASK WILL BE THE TIME TAKEN TO FLY THROUGH THE COMPETITION WINDOW, EXPRESSED IN SECONDS, ROUNDED TO ONE DECIMAL PLACE. (PARALOG 2017)

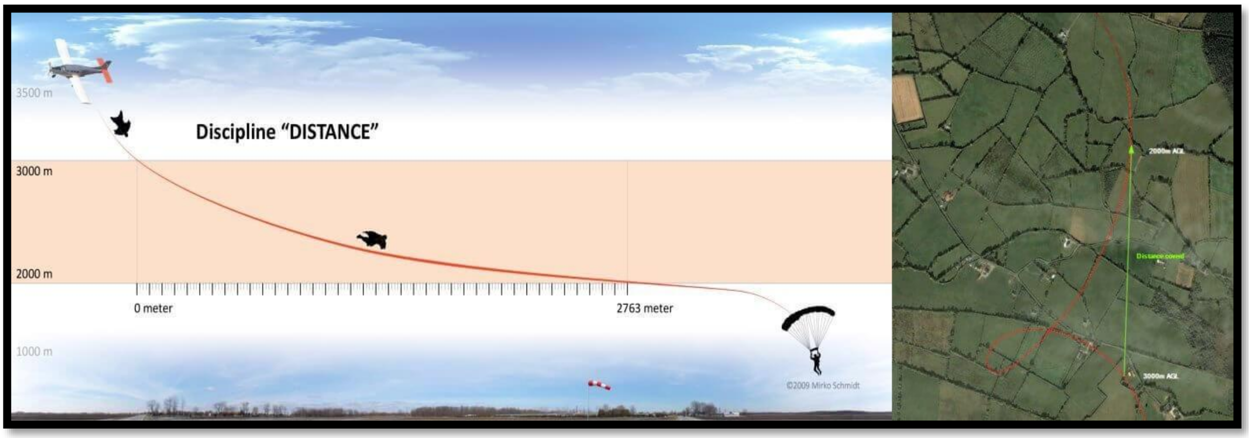


FIGURE 13DISTANCE TASK: THE WINGSUIT FLYER IS TO FLY AS FAR AS POSSIBLE THROUGH THE COMPETITION WINDOW. THE RESULT FOR THIS TASK WILL BE THE STRAIGHT-LINE DISTANCE FLOWN OVER THE GROUND WHILE IN THE COMPETITION WINDOW, EXPRESSED IN METERS, ROUNDED TO A WHOLE NUMBER. (PARALOG 2017)

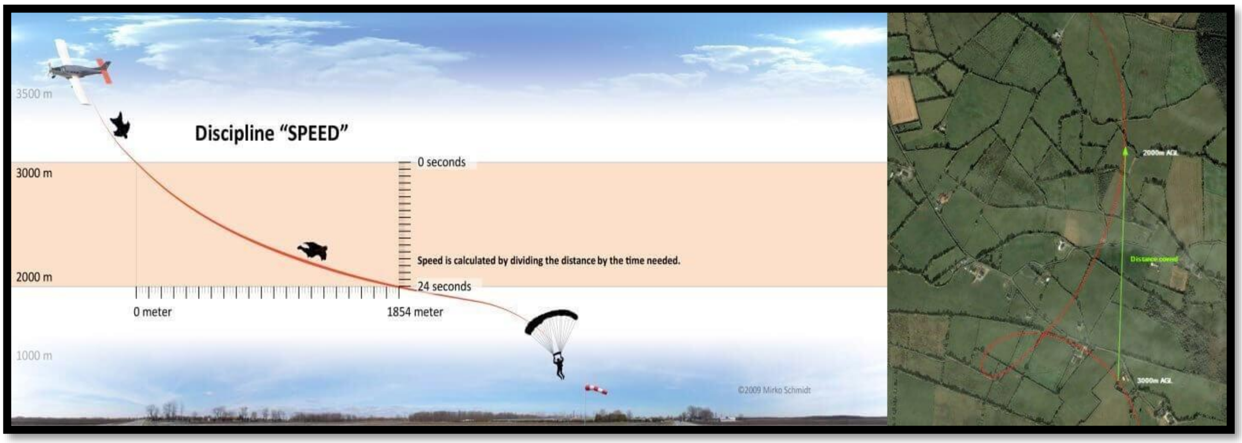


**FIGURE 14SPEED TASK: THE WINGSUIT FLYER IS TO FLY AS FAST AS POSSIBLE HORIZONTALLY OVER THE GROUND THROUGH THE COMPETITION WINDOW. THE RESULT FOR THIS TASK WILL BE THE STRAIGHT-LINE DISTANCE FLOWN OVER THE GROUND WHILE IN THE COMPETITION WINDOW DIVIDED BY THE TIME. (PARALOG 2017)**

An example of the data record of a current world record performance in the distance task is shown in Figure 15. This shows some of the performance capabilities of an expert level wingsuit.(paralog 2017)

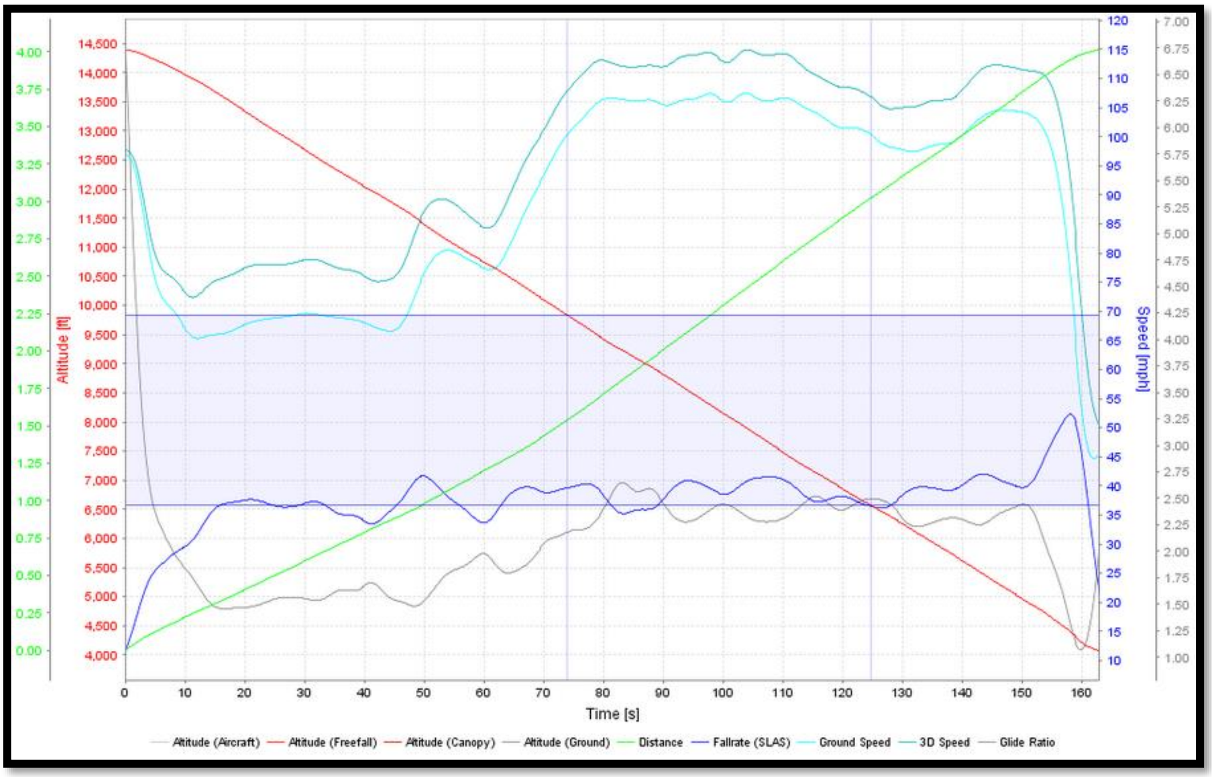


**FIGURE 15GPS DATA OF ALTITUDE, VERTICAL SPEED, HORIZONTAL SPEED, TOTAL SPEED, AND GLIDE RATIO OF A WORLD RECORD WINGSUIT FLIGHT IN THE DISTANCE TASK (PARALOG 2017)**

**ii.Wingsuit design depends on how expert the pilot is**, it can be categorized to:

- Beginner Level Wingsuits. Figure 16
- Intermediate Level Wingsuits. Figure 16
- Expert Level Wingsuits. Figure 17


**FIGURE 16: BEGINNER AND INTERMEDIATE WINGSUITS (SQUIRREL WS 2021)**


**FIGURE 17: ADVANCED WINGSUITS (SQUIRREL WS 2021)**

- **Beginner Level Wingsuits**

Beginner level wingsuits are easier to fly, more stable, more comfortable, and less restrictive than more advanced wingsuits. They are designed to safely train people new to the sport and give them experience to perform all the maneuvers necessary for wing suit flight. The arm wings and leg wings are usually separate, and the arm wings are designed so that the parachute controls and risers are accessible to the pilot without having to unzip or release the wings. See the example of a beginner suit in flight shown in Figure 18. (Sestak 2017)

**FIGURE 18: BEGINNER WINGSUIT (TONYSUITS 2010)**

**To use a beginner wingsuit, pilot must be experienced skydiver with at least 200 skydives and an appropriately rounded skill set. (squirrel ws 2021)**

- **Intermediate Level Wingsuits**

To fly an intermediate-size suit, pilot should have all the basic skills of beginner, plus at least 350 skydive with over 100 of them being in a beginner suit. In addition, pilot of intermediate wingsuit should have a solid grasp of basic free-flying skills from sit-flying to back-flying and should fully understand the proper techniques for entering, staying within, and exiting flocking formations. (squirrel ws 2021)

**FIGURE 19: INTERMEDIATE WINGSUIT WITH INCREASED ARM WING SIZE, END OF ARM WING GRIPPERS, AND AN EXTENSION OF THE ARM-WING DOWN THE LEG OF THE PILOT (TONYSUITS 2010)**

Intermediate suits Figure 19 the range of planforms are wider, but generally follow the same construction techniques as beginner level wingsuits with ram-air inflated designs.

- **Expert Level Wingsuits**

Before attempting to fly an advanced wingsuit, pilot should have all the previous skills, plus at least 450 skydive with over 100 of them being in an intermediate suit. That advanced wingsuits require a great deal of training to fly safely, pilot should have solid free flying skills, a thorough understanding of all aspects of skydiving, and excellent canopy skills. (squirrel ws 2021)

Expert-level suits are the largest; they have the highest performance, and are the least stable of wingsuits. They are typified by very large arm wings that are joined to the leg wings continuously along the leg wing leading edge to the feet of the pilot, making them one large, uninterrupted surface as shown in Figure 20. Expert wingsuits also have a leg wing extending beyond the pilot’s feet. Some expert-level wingsuits have a wider stance.(Flyteskool.ws. 2016)


**FIGURE 20: EXPERT LEVEL WINGSUIT (TONYSUITS 2010)**

## 6. The technology involved in designing the wingsuit

Designing a wearable aircraft, safely and comfortably considering the human body with the best aerodynamic performance is not an easy process. Following proven and well-documented systems engineering methodologies and a logical stepwise approach to wingsuit-design-as-aircraft-design should yield significantly better results approaching an optimal design within the constraints of current technology. (Sestak 2017)

For development of the wingsuit, it is imperative to scan the athlete in a flight-relevant posture. This applies, to arm and leg components, as the angles between legs as well as between arms and body are decisive factors for the formation of wing sizes and the posture of the flyer. (Ansari and Krzywinsk, Parametric geometry model design of a wingsuit 2020)

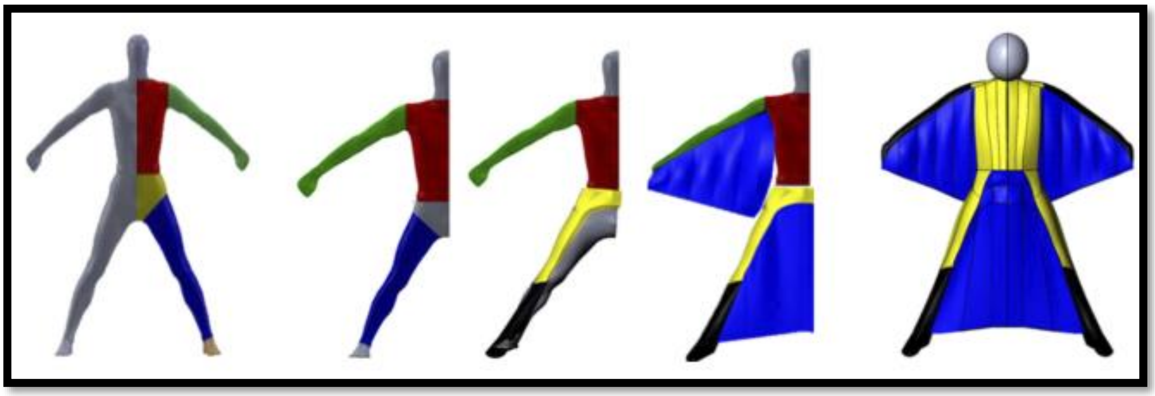

**FIGURE 21: DEVELOPED WINGSUIT IN THE FLAT POSTURE; LEFT: HUMAN BODY; CENTER: DESIGN STEPS FOR ARM/ LEG WINGS AND THE SUIT; RIGHT: ASSEMBLED WINGSUIT (N. ANSARI 2019)**

The availability of wide computer aided design (CAD) tools, somehow inexpensive and available computational fluid dynamics (CFD) software, and the ready availability of task-specific, web-based information and tools all allow current aircraft designers to access using sophisticated tools and methods which greatly improve designs and reduce time necessary for analyzing design decisions (Reed, Follen and Afjeh 2000)

A geometry model of the flight body is required to simulate the flight behavior. Depending on the complexity of the geometry, it can be generated with 3D CAD software solutions. In terms of anatomic objects, optical capturing solutions may be required. These optical measurement techniques enable the fast, precise, and contactless detection of technical or anatomical shapes. (Ansari and Krzywinsk, Parametric geometry model design of a wingsuit 2020)
There are different methods to scan an object for the development of a virtual 3D geometry model. Figure 22 for capturing the individual's body data, optical scanning methods are widely used. The most popular one among them is the full-body scanner, in which the subject stands on a turntable during the measuring cycle (360°)Figure 23

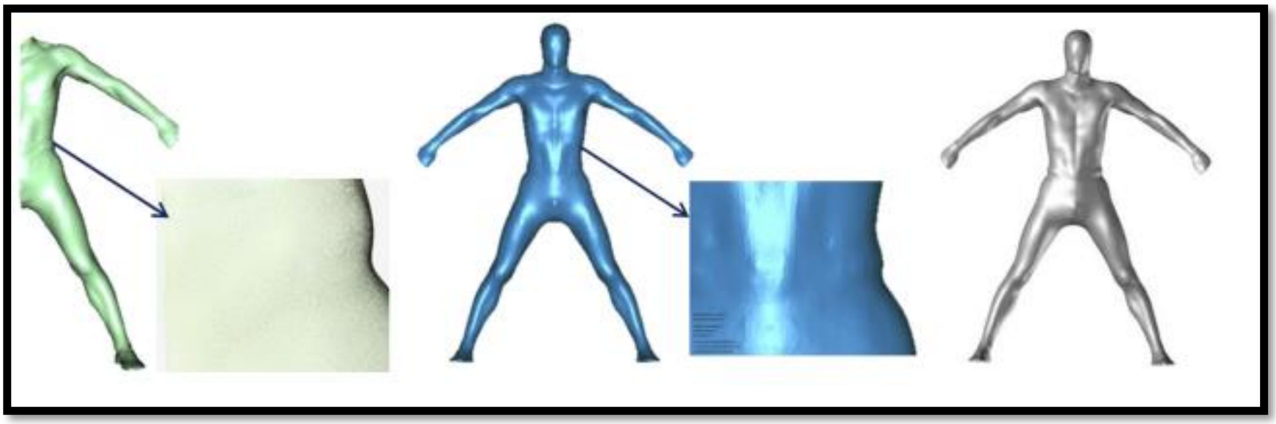

**FIGURE 22: LEFT: POINT CLOUD FROM THE SCANNER, MIDDLE: POLYGON SURFACES FROM GEOMAGIC STUDIO, RIGHT: SPLINE SURFACES FOR CAD SOFTWARE (N. ANSARI 2019)**

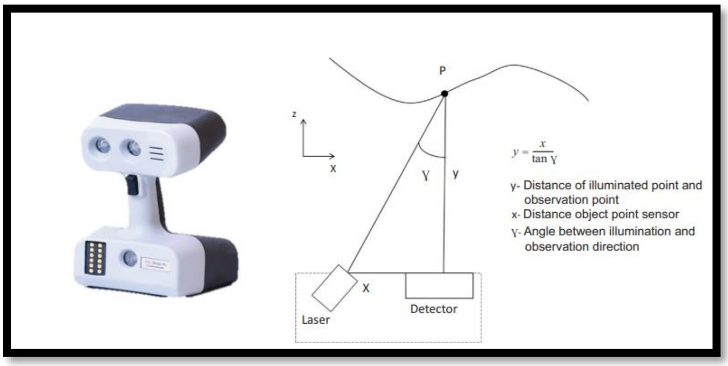


**FIGURE 23:LEFT: ARTEC MHT 3D SCANNER (HTTPS://WWW. ARTEC3D.COM/DE/3DSCANNER); RIGHT: TRIANGULATION, DRAWN AFTER (BEYER, 2002)**

Then the development steps that the surface data of the human body model imported to Solid Works for further processing. In this environment, the geometry can be divided into different parts (arm, head, legs, feet, and hip as "individual parts") to define the posture of the wing suit flyer. The desired position of each body part can be achieved by moving and rotating them shown in Figure 24 and Figure 25. (Ansari and Krzywinsk, Parametric geometry model design of a wingsuit 2020)

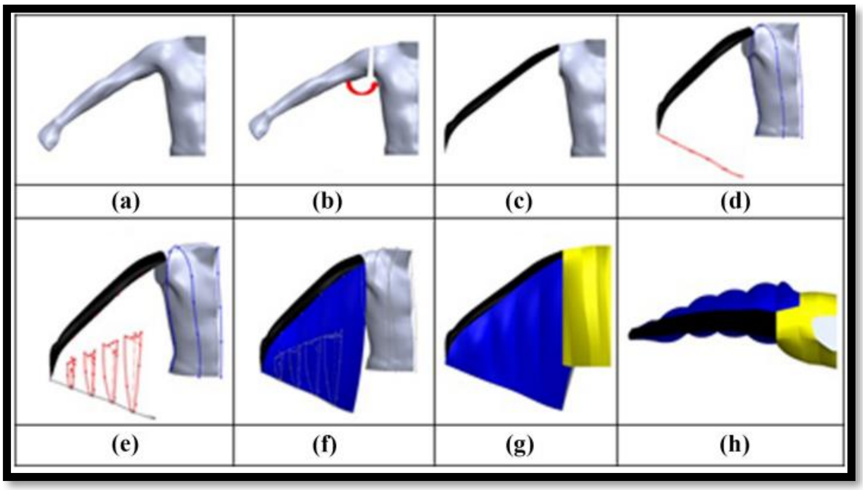


**FIGURE 24: SLEEVE/ARM WING DEVELOPMENT IN SOLID WORKS (N. ANSARI 2019)**

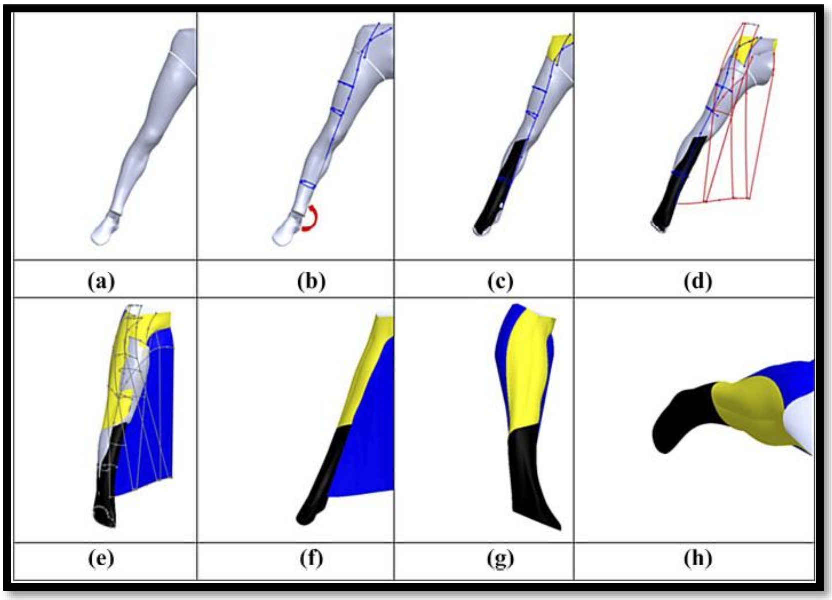


**FIGURE 25: TROUSER/LEG WING DEVELOPMENT IN SOLID WORKS (N. ANSARI 2019)**

The obvious performance measure for wingsuit is how much lift it produces. This can be assessed non-dimensionally in a wind tunnel or with a wind wall, by observation of the wingsuit's lift coefficient. Should we have time to gain the software expertise, this could also be assessed on ANSYS FLUENT flow solver software, example: Figure 26 and Figure 27. (Stephanopoulos, Levy and Jr. 2015)

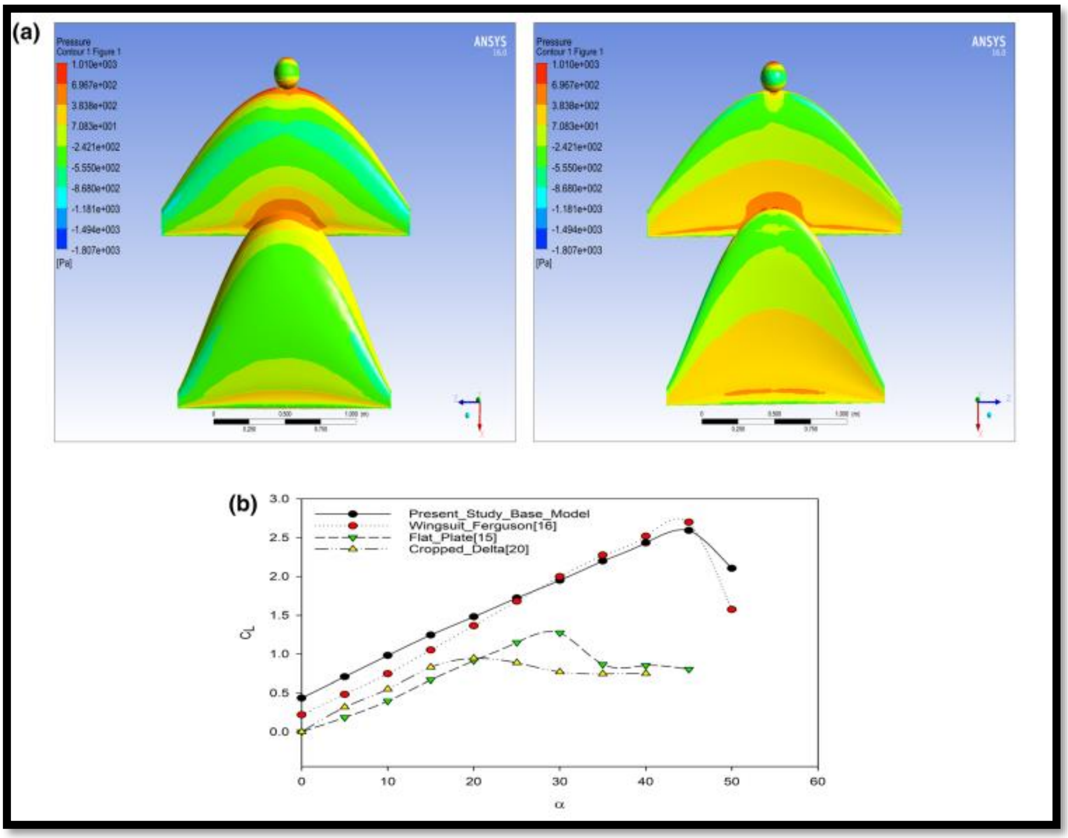


**FIGURE 26: A) PRESSURE CONTOURS FOR UPPER AND LOWER SURFACE AT A=0° RESPECTIVELY. B) LIFT COEFFICIENT VS ANGLE OF ATTACK FOR WINGSUIT BASE MODEL (CHANDRA AND TRIPATHI 2021)**

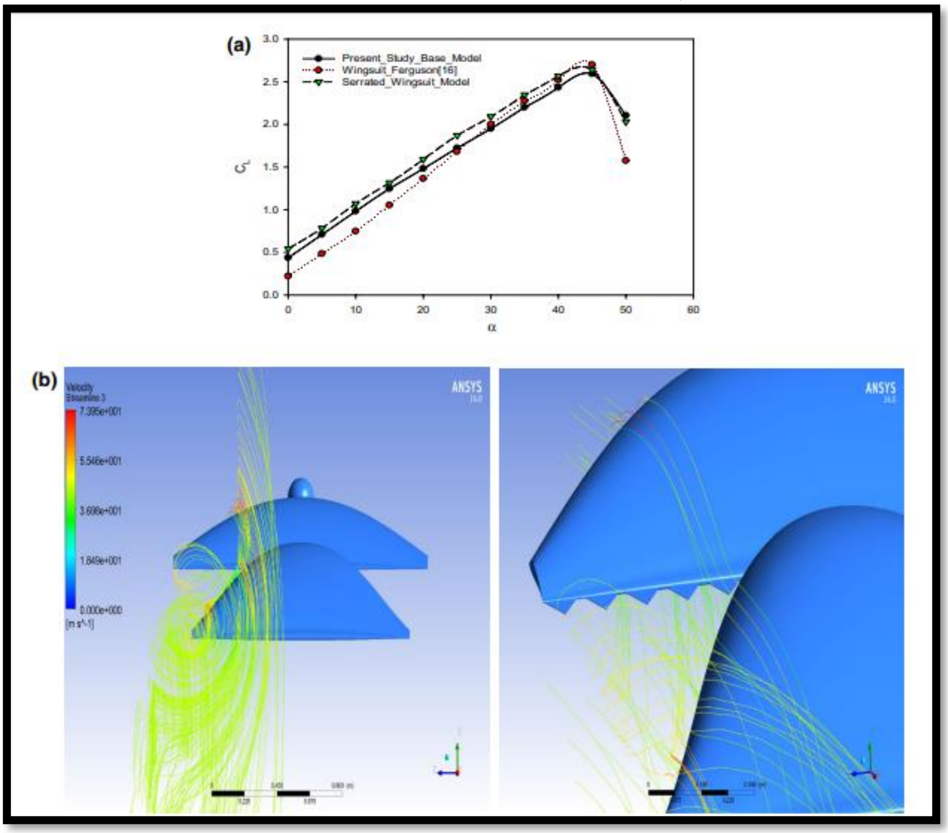


**FIGURE 27: A) LIFT COEFFICIENT VS ANGLE OF ATTACK FOR WINGSUIT SERRATED MODEL. B) VORTEX PRODUCED BY WINGSUIT BASE MODEL AND SERRATED MODEL RESPECTIVELY (CHANDRA AND TRIPATHI 2021)**

## Results:

● According to this research wingsuit can be improved to fulfill a required function needed, by involving technology, using new fabrics, and applying aerodynamic theory.

● Comparing the flight of a wing suit with flying squirrel, it could be easy to have a wingsuit that is completely controllable, safe and can easily land without a parachute.

● Realizing that the wingsuit design didn't change a lot from the first commercial wingsuit till now, gives us a chance to be pioneers in adding more functions to it.

## Recommendations:

● The research recommends manufacturing the wingsuit in Egypt as it will be very useful for entering a new open market in the field of skydiving.

● The research recommends applying more technological studies in wingsuit designing and materials to be suitable for military usage.

● The research also recommends establishing an Egypt project through which scientific studies for the design and production of a wingsuit will be completed, in cooperation with the institutions supporting and sponsoring such activities, to keep pace with the modern technological development in the field of free flight.

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