1/3rd Scale Mita Type 3 Production Notes

The first part of a multi-part series.

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This article was translated from the original Japanese by the author.

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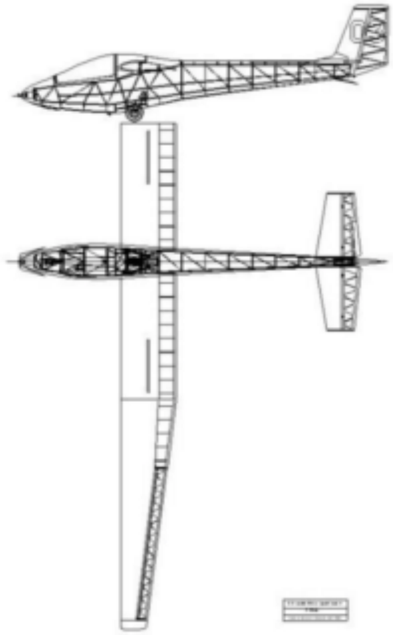
Nowadays, the mainstream to enjoy radio-controlled aircraft is to assemble a ready-made semi-finished aircraft (so-called ARF aircraft) , but one of the best parts of the RC hobby is to design your own aircraft, cut out the parts from the materials and assemble it by yourself. Collecting the aircraft's data and studying them, making drawings and revising them until you are satisfied, cutting parts and assembling them through overcoming many obstacles and unexpected mistakes, you can finally build your favorite aircraft. You will be satisfied with a sense of accomplishment that you can't experience with ARF aircraft and you will be attached to the aircraft.

He may used to enjoy building toys when he was a kid, but as grew up, he doesn’t have the opportunity to do so anymore. What is more, as many ARF products are readily available today at a reasonable price, there are many people who hesitate to start building their own products. Although there are many articles of self-made aircrafts on RC magazines, they usually do not describe how they dealt with the many considerations that arise in the design and building process and how they overcame the inevitable mistakes in the project. Therefore, the readers tend to think that it was made by a person who is very good at craftsmanship and it is far away from them.

It was the same with me. I had been away from model making for several decades since junior high school. I started my hobby of RC airplanes just after I retired. At first I enjoyed assembling ARF and building balsa kit airplanes, but a strong desire to design and manufacture my own airplanes from scratch has gradually grown. So, for the first time in decades, I took up the challenge of making drawings with a 2D CAD and cutting parts from materials with cutters, saws, and files and assembling them. There were many things to consider in the design stage, and I made many mistakes in the fabrication stage. I believe that reporting the process without hiding would be helpful to those who are interested in making their own products. This is the reason I am writing this article. I hope you will enjoy reading this article, even if it is a bit long and I hope it will give a push to those who are hesitant about building their own RC.

The subject of this article is a 1/3 scale Mita Type 3 revision 1 glider that was introduced in the November 2019 issue of Japanese RC magazine “RC Technology（ラジコン技術）”. It is a large plane with a wingspan of over 5.3 meters, and is the second plane that I designed and built completely by myself.



How It All Started

After retiring, I took up RC airplanes as a hobby. There are many types of airplanes, but I am particularly fascinated by the elegant flying style of gliders. Among the many different types of RC gliders I have built, the 1/5 scale Mita Type 3 revision 1, which I built from a kit from Thermal Studio, has become one of my favorites.

The photo below was taken on her first flight just before landing. As I was so impressed with its graceful appearance I wanted to buy a larger 1/3 size. Because no kit was available, I decided to make it by myself.

Photo 1: 1/5 scale Mita Type 3 rev 1 made from Thermal Studio's kit.

Aircraft Survey Part 1

I immediately started a survey of the actual Mita Type 3 at the end of 2017. I found that the owner of JA2103, which was the original aircraft of the 1/5 kit of Thermal Studio, lives in my city Utsunomiya. I contacted him, Mr. Kimura, and visited his house at the end of the same year. Unfortunately, he had donated the aircraft to the Shizuoka University of Science and Technology's Aviation Museum, so I was unable to see it. However, he gave me a CD with valuable photos of each part of the aircraft taken during the time he owned it, which helped me a lot in the design process.

In parallel with this survey, I began full-scale two-view drawing of the 1/3 scale using CAD, based on the 1/5 three-view drawing. Its purpose was to clarify any unclear points that needed to be surveyed. Unfortunately, I am not able to use 3D CAD, I used 2D AR_CAD, a free software.

Aircraft Survey Part 2

At the beginning of the year 2018, the Kanto region was hit by a rare heavy snowfall. 3 days later, I visited the Shizuoka Aviation Museum near Shizuoka Airport to investigate the actual aircraft. As expected, there was no snow at all. I was able to see the actual Mita Type 3 rev 1 for the first time.

Photo 2: The actual Mita Type 3 rev 1 JA2103 at the Shizuoka Aviation Museum (borrowed from the internet aviation magazine HIKOKI-KUMO)

My first impression was that it was smaller and slimmer than I had expected. I imagined the diameter of the steel pipes used for the fuselage to be about 30Φ, and started drawing with that dimension, but when I compared it with the photo on the CD that I received at the end of the last year, I had the impression that it must be smaller. By seeing actual aircraft, I was surprised to find that the biggest longitudinal longeron was 20Φ, and others were 15, 12, and 10Φ.

Thanks to the kindness of the museum staff, who took time out of their busy schedule to help me, I was able to understand how the center and outer wings are connected, how the wing is attached to the fuselage, and the leading edge shape and hinge positions of the ailerons. Nowadays anything can be found on the Internet, but I felt again that it is important to see the real thing and appeal to my senses.

I was greatly encouraged by the museum's willingness to examine the actual object if there would arise unclear points in the design process and ask him through e-mails.

Photo 3 shows the connection between the outer and center wings. It was taken from the wing leading edge. The two wings are connected by big fittings protruding from both wings at a distance of about 10 cm. The connection is made by two shear bolts located at the height of the upper and lower spar flanges. The upper bolt is visible in this photo. The gaps between the wings are closed with a plastic cover.

Photo 3: Joint of the center and outer wings of the actual aircraft.

Photo 4 shows how the wing is connected to the fuselage. There are two fittings, front and rear, but this is the front one. Two bolts protruding from the square fuselage frame penetrate through the holes in the tongues of the two fittings which are attached to the wing web and are tightened with nuts. Lift and drag forces and rolling moment are efficiently transmitted to the fuselage.

Photo 4: Wing-fuselage joint of the actual aircraft (front side).

I was able to take a number of other valuable photos.

Actual Aircraft Data

Here, the actual machine data of Mita type 3 revision 1 is summarized as follows.

Form		Double-seat glider
First flight		March 26, 1966
Number of production		32
Structure	Fuselage	Steel tube truss covered with cloth
	Wings	Wooden single-spar covered with cloth. Consist of three parts: 1 center wing and 2 outer wings.
Main Characteristics	Wingspan	16m
	Overall length	7.96m
	Overall height	1.57m
	Empty weight	300Kg
	Gross weight	450Kg
	Wing area	15.87m2
	Aspect ratio	16.3
	Dihedral angle of the outer wing	3.45°
	Twist	Twist is provided on the outer wing, but its magnitude is unknown.
	Airfoil	NACA 633-618
Performance	Best glide ratio	30.8
	Best glide speed	78Km/h (single-seated) 82.7Km/h (double-seated)
	Minimum sink rate	0.72m/sec (at MaxGW)
Flight Limitations	Excess prohibition degree	180Km/h
	Stall speed	62.5 Km / hour (double-seated)
	Limit load factor	+5.0~-2.5
	Allowable center of gravity range	30% MAC ~ 40% MAC (312mm ~ 416mm from the front edge of the main wing)

These data will be used as a reference to determine the specifications of the 1/3 model.

Basic Concept of the 1/3 Model

Now that the basic survey of the actual model is complete, it is time to solidify the basic concept of the 1/3 model. As a policy, I decided to preserve as much as possible the image of the actual model and if necessary omit or simplify without destroying it. There are five items that must be defined as the basic concept as follows.

1. *How to divide the model?* How to divide the body and wings so that they can be carried by my Subaru Forester?

2. *How to make the fuselage structure?* The fuselage of the Thermal Studio's 1/5 model is made of laser cut plywoods, but I don't have a laser cutter.
3. *How to join the center and the outer wings?* The joining method of the actual aircraft is as described above, but should it be faithfully modeled or should a different method be used?
4. *What airfoil should be used?* Since the Reynolds numbers in flight are different between the actual aircraft and the 1/3 model, the aerodynamic characteristics of the airfoils such as lift and drag will change. Therefore, there is a concern that the performance of the actual airfoil will be degraded.
5. *How much is the target weight?* Weight control is important In the development of airplanes. Target weight must be set and the weight and center of gravity must be monitored during each process of design and building, otherwise overweight may result in unsatisfactory flight performance.

Above five basic items have been sequentially solidified as follows.

Basic Concept #1: Division of the Model

The actual aircraft is divided into 5 parts: center wing, outer wings (2), fuselage, and horizontal tail. In addition, the rudder can be detached relatively easily, so the fuselage length can be reduced slightly. The 1/5 model of Thermal Studio is divided basically the same way as the actual model

Now, the dimensions of each 1/3 model are as follows.

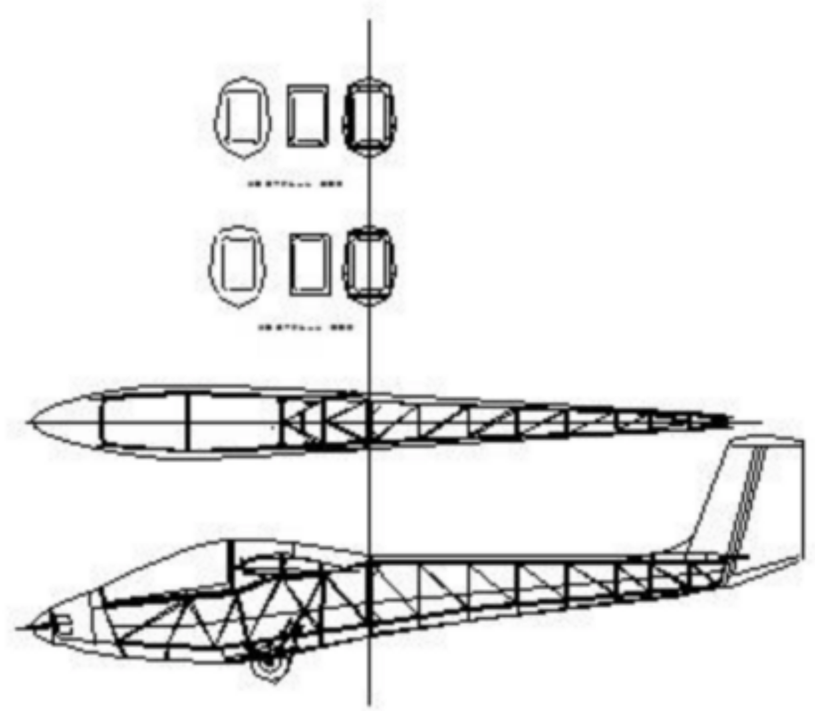
Central wing	2,000mm
Outer wing	1,670mm
Body	2,654mm (With ladder attached)
	2,526mm (With the ladder removed)
	2,394mm (With the vertical stabilizer removed)
Horizontal stabilizer	996mm

On the other hand, the carrying capacity of my Subaru Forester for long objects is as follows.

With the back seat down	1,600mm
When passing through the gap between the driver's seat and the passenger seat as above	1,700mm
When the passenger seat is knocked down and hits the dashboard	2,600mm
When hitting the windshield as above	2,800mm

Above conditions were used to determine the division method, but I worried a lot and went through many changes. The outer wings can be carried easily if they are placed through the gap between driver's and front passenger's seats. The problem is the center wing and the fuselage. In the beginning, I decided to simply fold down the front passenger seat to make the same division as the actual aircraft. However, it is best to carry the plane without folding the front passenger seat. If the center wing is split in two, it will not look bad and the length will be reduced to 1 meter. It is relatively easy to assemble by placing 2 or 3mm thick aluminum plates on the front and back of the webs and tightening them with bolts.

The problem is the fuselage. The fuselage is still too long even if the vertical fin can be removed, so it needs to be divided into two parts. If you divide the fuselage into two parts just behind the trailing edge of the main wing, the front fuselage will be about 1,200mm and the rear fuselage will be about 1,200 to 1,300mm. Drawing 1 shows how to split the fuselage in this way.



Drawing 1: Fuselage split plan

The idea is to make two frames of almost the same shape at the end of the front body and at the leading edge of the rear body, using 4mm and 5.5mm thick plywood respectively, and connect them with four M4 bolts at the four corners.

The 5.5mm plywood will provide the strength, and the 4mm plywood will maintain the outer shape. I decided to go ahead with this for quite a while, but the main disadvantage of this method is that the beautiful cloth covered fuselage will have a clear dividing line.

Furthermore, no matter how flat the plywood frames are, the tension force of the cloth will cause their distortion and a gap will appear in the dividing line. This is a big disadvantage to a scale aircraft. Also, weight of the rear fuselage will increase by a little less than 200g due to this division. Even if this is not the case, I was worried about the aft center of gravity, so I decided to avoid this idea.

Finally I decided to give up the idea of dividing the fuselage into separate sections. Giving up the idea of dividing the fuselage meant that the front passenger seat would be folded down, so I also decided not to divide the center wing. In the end, I went back to my original plan and decided to divide the model into seven parts: center wing, two outer wings, fuselage, horizontal tail, vertical stabilizer, and rudder.

Basic Concept #2: Fuselage Structure

The fuselage structure of the 1/5 model of Thermal Studio is a complex and elaborate combination of laser cut panels of plywood. The structure is light and has high rigidity. However, I don’t own a laser cutter and even if I were to rent a cutter by the hour, it would take a lot of time and cost a lot due to the complex structure.

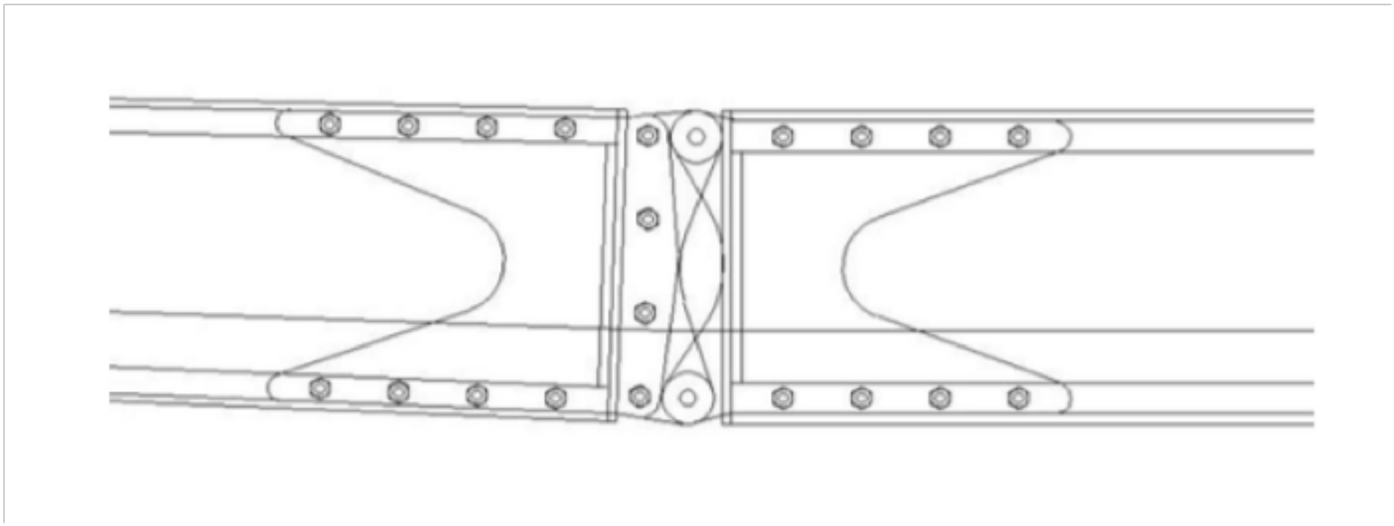
So this time, I decided to use carbon pipes to build a truss structure similar to the actual aircraft. Initially I thought about using aluminum pipes, but I chose carbon because it is lighter, more rigid, and available in various diameters. Another advantage of carbon pipe is that it can be easily glued with CA or epoxy adhesive. However, it may be a little difficult to cut, but preliminary experiments with a diamond cutter obtained from a hundred-yen store (one-dollar store) attached to a mini-router showed that it was rather easy to cut!

I hoped this would allow me to reproduce more realistically the image of the actual steel pipe truss structure.

After the completion of this model, I submitted an article to the Scale Soaring UK (SSUK), and this carbon pipe fuselage structure attracted a lot of attention. It was also evaluated as a breakthrough if this method can withstand landing loads. So far, there have been no cracks or peeling of adhesives, and the structure is fully usable.

Basic Concept #3: How To Connect the Outer and Center Wings

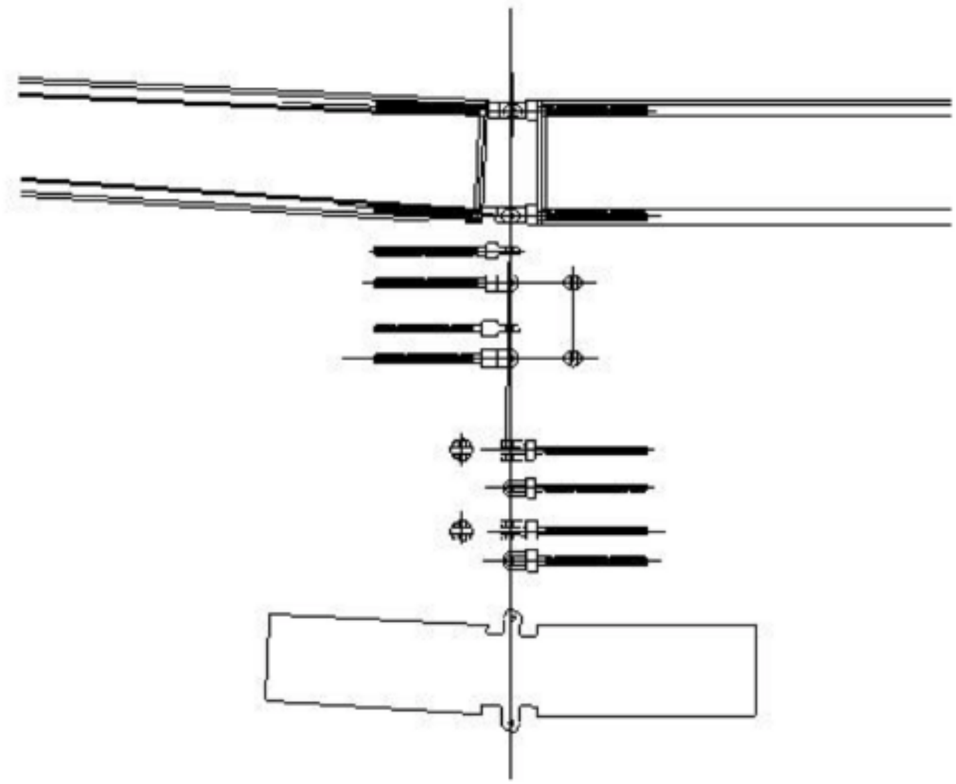
In the actual aircraft, there is a gap of about 10cm between the outer wing and the center wing, as mentioned earlier. The joint fittings extend from the both wings and are fastened with two shear bolts. Initially, I thought that since I was building a large 1/3 scale model, I would try to make it as similar as possible to the actual aircraft and planned a similar joining method. Drawing 2 is the first model I came up with to simulate the actual aircraft.



Drawing 2: Initial concept of the connecting method between the outer and center wings.

The fittings bolted to the flanges of both wings are stretched out and connected with two coupling bolts. This is the most typical method of joining the two wings, but a milling machine is required to make these fittings. One of my RC friends is good at metal processing and I sometimes ask him to make special fittings, but he only has a mini-lathe. I could ask a metal fabrication shop to make the fittings, but it would be quite expensive.

So, the next idea was to use the metal fittings that can be made only with a mini-lathe, as shown in Drawing 3.



Drawing 3: Connecting method of outer and center wings that can be made only with a mini-lathe.

The flanges of both wings are made of carbon square pipes, and four bolts are inserted into the pipes and glued into place. The plate at the bottom is a jig to accurately set the dihedral angle of the outer wing during assembly. With this method, although the flat part of the bolt head needs to be filed by hand, it can be made with a mini-lathe. At first, I thought it would be a good idea to proceed with this idea. The problem, however, was the plastic cover to close the wing gap. As I have no experience in making plastic parts, I am not very good at making a cover that fits perfectly into the sharp curve of the leading edge and figuring out how to attach it.

Finally, I decided to connect the two wings with carbon pipe, which is a common practice in RC airplanes, for the sake of appearance and ease of assembly and disassembly. Therefore, the two wings are perfectly aligned without any gaps. However, the metal fitting method has a high quality appearance that sets it apart from ordinary RC models, I was left with some regrets.

Basic Concept #4: Airfoil

The actual airacraft's airfoil is the NACA 633–618 developed by NACA, the predecessor of NASA. I had forgotten the nomenclature of the 6 series, so I reconfirmed it here.

The first 6 means that it is a 6 series (laminar flow airfoil series). A laminar airfoil series shifts the position of the lowest pressure on the upper surface backward by placing the maximum thickness of the airfoil relatively back. By doing so, the airflow from the leading edge to the maximum thickness is accelerated, and the air flow in that area is maintained as laminar flow (neatly organized flow) to achieve an airfoil with low drag. The next 3 means that the minimum pressure is set at 30% of the wing chord length from the leading edge. The next number 3 is a counterpart to the 6 that follows. In other words, the fourth number 6, means the design lift coefficient and the 3 in front of it tells us that the drag is low in the range of ±0.3 around the design lift coefficient. In other words, the design lift coefficient of this airfoil is 0.6 and the drag is low in the range of 0.3 before and after the design lift coefficient, that is, in the range of 0.3 to 0.9. The last two digits 18 refer to the wing thickness which means that the wing thickness is 18% of chord length.

In general, the aerodynamic performance (maximum lift coefficient and drag coefficient) of an airfoil becomes better the longer the chord length and the higher the flight speed. In other words, the greater the product of wing chord length and flight speed, the better the aerodynamic performance. The value of this product is called the Reynolds number Re, which is the product of the wing chord length and the flight speed divided by the kinematic viscosity of the air, written as $Re=(C*V)/\nu$, where C is the wing chord length, V is the flight speed, and ν is the kinematic viscosity of the air, with a value of 1.50E-05 m2/sec. The Reynolds number Re is the ratio of the inertial and viscous forces of the air on the airfoil. In other words, the larger the Re, the less the effect of viscosity and the better the aerodynamic performance of the airfoil.

The problem that arises is the difference in Reynolds number between the actual aircraft and the 1/3 model, so let's examine this next. The wing chord length C of the actual model is 1.2m in the center wing, and the outer wing tapers from 1.2m to 0.54m. The typical wing chord of such a tapered wing is called Mean Aerodynamic Chord (MAC) and in the case of the Mita, the MAC is calculated to be 1.04m. In contrast, the MAC of the 1/3 model is 1/3 of that, or 0.347 m.

Next, let's consider the flight speed V as the best glide speed. The best glide speed of the 1/3 model is not yet known, but the approximate value is estimated as follows. The lift force L acting on the wing during glide is balanced by the weight W of the aircraft. The lift force is given by $L=1/2\rho V^2*S*CL$. where ρ is the air density, S is the wing area, and CL is the lift coefficient. Since the lift force L is balanced with the weight W, we can replace L with W and transform the equation to $V=2*\sqrt{}(W/S)/(\rho*CL)$

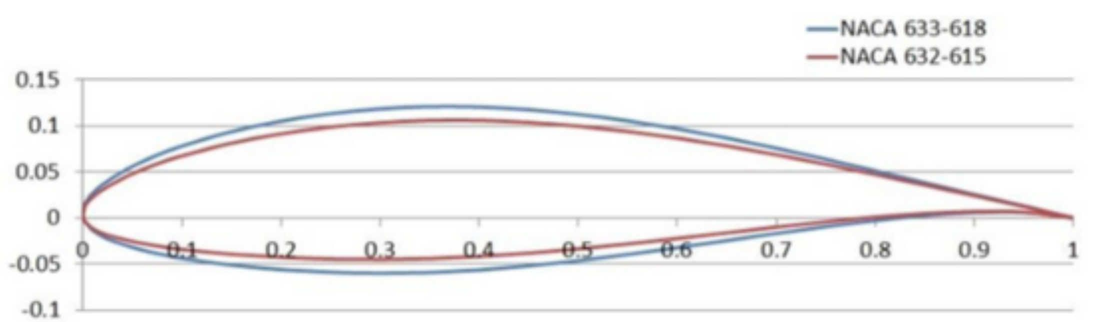
The air density ρ is the same for both the actual aircraft and the 1/3 model. The lift coefficient CL is also not so different. Then, the flight speed V is proportional to the square root of W/S, that is, the weight per unit area (wing loading). The wing loading of the actual aircraft is W=450Kg and S=15.87m2, which gives W/S=28.36. The weight of the 1/3 model is still not exactly known at this stage, but it should be less than 10 kg, as will be discussed in the next section, "Basic Concept #5 Target Weight". Let's assume W=10Kg, and S=1.76m2, so W/S=5.68. Therefore, the square root of the wing loading of the 1/3 model is 0.445 of that of the actual aircraft, and the best glide speed is about 0.44 times that of the actual aircraft, or about 10 m/sec.

Based on the above, the Reynolds numbers of the actual model and the 1/3 model are approximately as follows.

$$\text{Actual machine } Re = 1.04 * 23.0 / 1.50\text{E-}05 \fallingdotseq 1.6\text{E} + 06 = 1{,}600{,}000$$

$$\text{Model } Re = 0.347 * 10 / 1.50\text{E-}05 \fallingdotseq 2.3\text{E} + 05 = 230{,}000$$

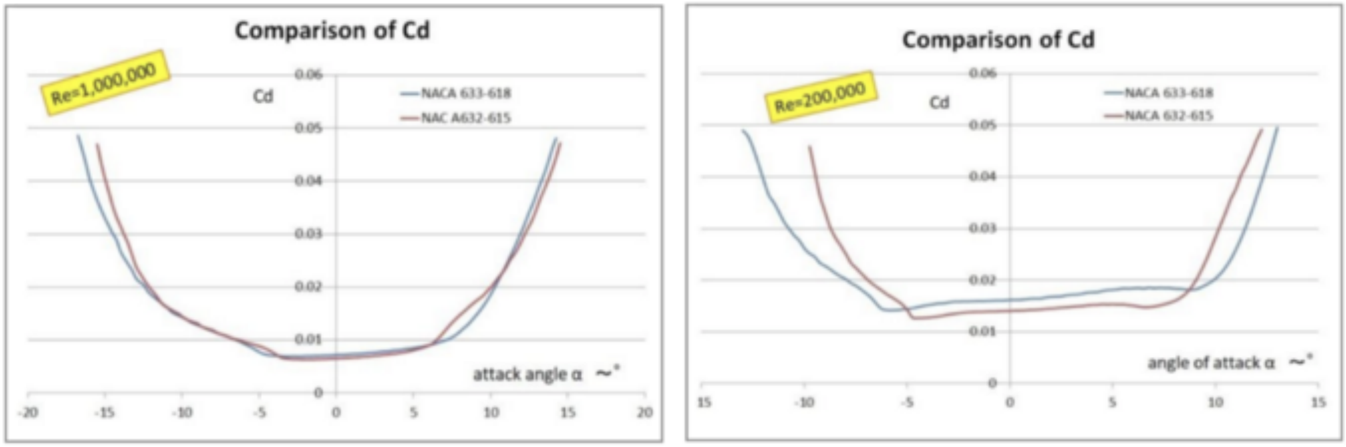
In other words, the aerodynamic performance of the airfoil is expected to be much worse than that of the actual aircraft, since the model has a Reynolds number of 230,000 compared to the actual aircraft’s 1,600,000, which is about 14% of the actual aircraft. Therefore, I wanted to adopt an airfoil that has good aerodynamic performance as much as possible with the Reynolds number and does not destroy the silhouette image of the actual airfoil. It’s the NACA632–615. Both airfoils are shown below.



Drawing 4: Airfoils comparison

The difference in silhouette is almost imperceptible when the cross section is not visible.

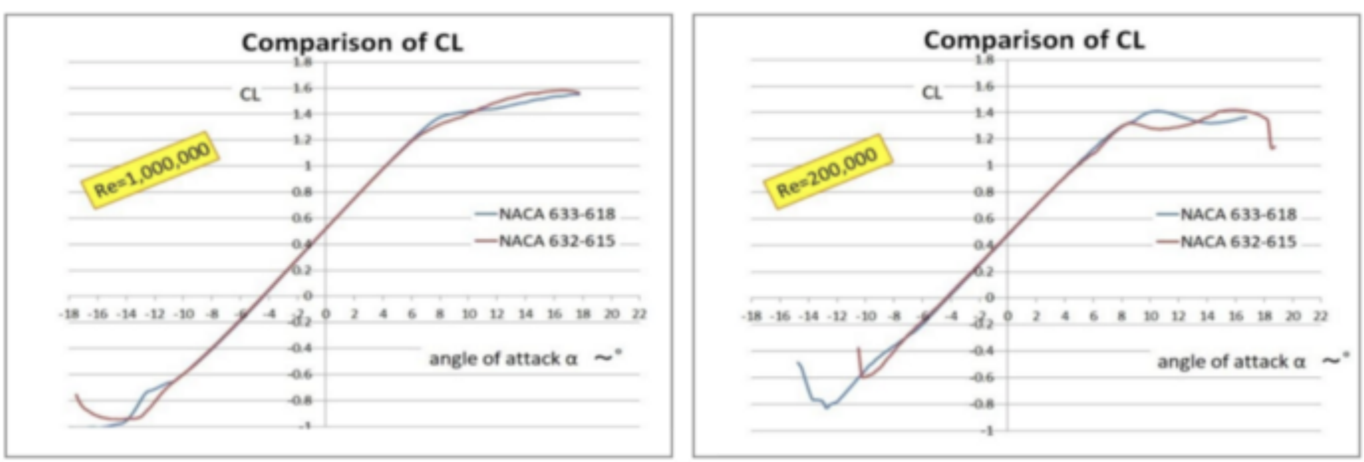
Next, let’s compare the aerodynamic performance of both airfoils. The data I had at hand was 1,000,000 and 200,000 Reynolds numbers, so I use 1,000,000 as the actual Reynolds number and 200,000 as the 1/3 model Reynolds number. First, let’s compare the drag coefficient.



Graph 1: Comparison of drag coefficients for both airfoils

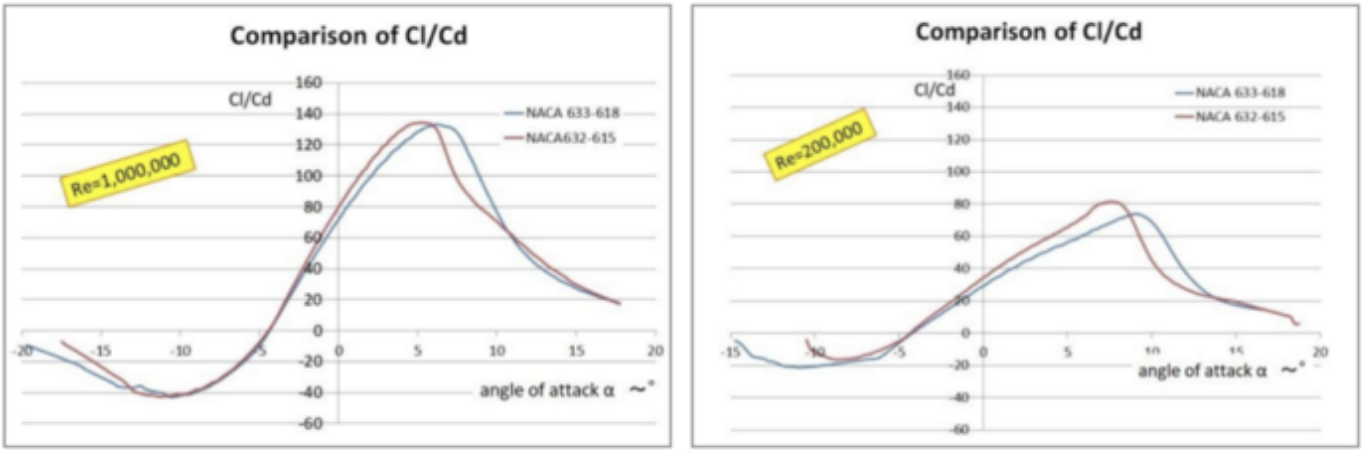
At the Reynolds number of 1,000,000, the drag coefficient of the two airfoils is almost the same, and it keeps a very small value of about Cd=0.007 between -4° and +6° angle of attack. On the other hand, at the model Reynolds number of Re=200,000, the drag coefficient of the actual airfoils 633–618 is 0.016 to 0.018 even at the low angle of attack which is more than double the value at Re=1,000,000. On the other hand, for 632–615, the value is only doubled to 0.014–0.015.

On the other hand, the lift coefficient is almost the same for both airfoils, whether Re = 1 million or Re = 200,000, as shown below.



Graph 2: Comparison of lift coefficient for both airfoils.

From these data, the lift-drag ratio (CL/Cd), the ratio of lift to drag that is important for gliders, is as follows:



Graph 3: Comparison of lift and drag coefficients for both airfoils.

At Re = 1,000,000, the lift-drag ratios of both airfoils are almost the same, and the maximum lift-drag ratio is over 130. At Re=200,000, the 632–615 clearly shows better characteristics up to the stall angle around 7.5° angle of attack due to the difference in drag coefficient. The maximum lift-drag ratio of the 632–615 is 81.6 and that of the 633–618 is 72.2, with the former being about 13% better.

From the above, it is clear that there is almost no difference in performance between the 18% and 15% airfoils at the actual aircraft's Reynolds number. The thicker the wing, the easier it is to secure structural strength and rigidity, so it is easy to understand why the actual aircraft adopted the 18% wing section. On the other hand, since the maximum lift-drag ratio of the 1/3 model is drastically reduced to 72.2/132 = 0.55 of the actual one, I decided to use a 15% airfoil to keep the glide performance deterioration as minimum as possible.

Basic Concept #5: Target Weight

The last item in the basic concept was to determine the target weight. I intended to set the target weight by estimating the weight of the 1/3 model from the weight data of the actual aircraft and the 1/5 model I had.

Square/Cube Law

In the real world of aircraft development, when developing a new aircraft, the weight of the aircraft is sometimes estimated roughly at the very early stage of planning, where many things have not yet been decided, using a law called the "square/cube law". This is a method of estimating the weight of a new aircraft based on data from similarly shaped aircraft of known weight, where the area is proportional to the square of the size ratio (dimension ratio) and the weight is proportional to the cube. For example, the wing area of a similar aircraft of half the size would be 1/2 x 1/2 = 1/4, and the weight would be 1/2 x 1/2 x 1/2 = 1/8.

It is obvious that the area is reduced to 1/4, but the fact that the weight is reduced to 1/8 means that we assume both aircrafts have the same construction of the same material but length, width, and thickness are halved.

Initially, I used this square/cube law as a starting point and made the necessary modifications to predict the weight of the 1/3 model.

Points To Keep In Mind When Estimating the Weight of a Glider

When estimating the weight of an ordinary prop plane, it is enough to estimate the empty weight, but the situation is different for a scale glider. The empty weight of the Mita Type 3 rev 1 is 300 kg, but with no pilot on board, the center of gravity is too far back and of course it cannot be flown as an unmanned aircraft equipped with R/C equipment. 450 kg is the maximum full load weight with two pilots on board, so the weight (payload) is really half of the empty weight. This is a situation where the center of gravity is aligned. Therefore, to estimate the weight of a model glider, you need to consider both the empty weight and the payload.

All of my model gliders have a motor and foldable propeller in the nose. This is to make it easy to enjoy flying even on level ground. Naturally, the weight of such equipment, which is not included in the actual model, is treated as payload. The weight classification of the equipment on the model glider is as follows.

Payload treatment	Motor, folding propeller & hub, LiPo for power, amplifier, receiver, power supply for receiver & S / W
Treated as empty weight	Servo, extension cord for servo

The servos and extension cords are treated as empty weight because the links and cables of the control system are also included in the empty weight of the actual aircraft.

Weight Data of the Actual Aircraft and the 1/5 Model

The empty weight and payload weight of the actual machine and the 1/5 model are as follows:

	Actual Machine	1/5 Model
Empty weight	300Kg	2.10Kg
Payload	Up to 150Kg	0.665Kg
Flight Weight	Up to 450Kg	2.77Kg

The materials and construction style are quite different between the real aircraft and the 1/5 model, but if we forcefully apply the square/cube rule to the real aircraft, we get:

1/5 Model Predicted Empty Weight = 300 × 1/5 × 1/5 × 1/5 = 2.40Kg

Maximum payload = 150 × 1/5 × 1/5 × 1/5 = 1.20Kg

It is surprising that the empty weight is close to the actual measured weight of 2.10 kg. The actual empty weight of the model is finished at 87.5% of the predicted value. The payload is only a little over half of the maximum payload prediction because of the heavy motor mounted in the nose. In this condition, the center of gravity is O.K. without additional weight.

Predicted Weight of the 1/3 Model (Initial)

Initially, using this square-cube law, I predicted the weight of the 1/3 model as follows.

1. Empty Weight

Predicted from the data of the actual machine	300Kg×1/3×1/3×1/3=11.11Kg
Considering the difference in structure and materials between the two, and assuming 87.5% of the above predicted value in accordance with the actual results of the 1/5 model	
	11.11×0.875=9.72Kg
Based on the 1/5 model, estimated value	2.10Kg×5/3×5/3×5/3=9.72Kg
Of course both estimated values are the same	

2. Payload

Payload without weight is estimated from the actual value of 1/5 model 0.665Kg × 5/3 × 5/3 × 5/3 = 3.08Kg

Assuming that the maximum payload is half the empty weight like the actual machine, 9.72Kg x 0.5 = 4.86Kg

From the above, the flight weight is as follows.

During normal flight without weight	9.72+3.08=12.80Kg
At maximum full weight with weight	9.72+4.86=14.58Kg

Revised Estimated Weight of the 1/3 Model (Target Weight)

In the beginning, I predicted the weight as above, but in the process, I noticed the following. When I drew the wing plans, I found that the thickness of the materials in the 1/3 model and 1/5 model did not need to be much different. The ribs, planks, etc. are almost the same as in the 1/5 model, 2 to 3 mm thick balsa is needed. The covering material, which is relatively heavy, will be the same since it will be covered with the Oratex. This means that the weight of these materials will increase by the square of the dimensions, not the cube.

Furthermore, the weight of the fuselage structure of the 1/3 model will not increase as much as the cubic law, since it will be assembled with carbon tubes as opposed to the plywood of the 1/5 model.

Based on the above, the weight of the 1/3 model is estimated by multiplying the 1/5 model by the square of the scale ratio. Since there is weight data of the main components of the 1/5 model, the values below are the weights of the main components of the 1/3 model estimated by the square law.

	1/5 Actual Weight	1/3 Estimated weight
Left outer wing (including aileron servo)	242g	672g
Right outer wing (same as above)	244g	678g
Central wing (including spoiler servo)	585g	1,625g
Fuselage (including tail wings and servo for it)	1,029g	2,858g
Total (empty weight)	2,100g	5,833g
Payload (motor, LiPo, etc.)	665g	1,847g
Remeasurement (normal flight weight)	2,765g	7,680g
Maximum total weight (empty weight x 1.5)		8,750g

After rounding, the target weight of 1/3 Mita type 3 rev 1 was set as follows:

	Target Weight
Left outer wing	700g
Right outer wing	700g
Central wing	1,600g
Body	2,800g
Empty Weight	5,800g
Payload	1,800g
Normal Flight Weight	7,600g
Maximum Total Weight	8,700g

> ***Mistake 1:*** *Unfortunately, as will be shown later, the finished weight has reached about 10 kg due to the installation of equipment such as landing gear shock absorber, instruments panel, seats, tow line release mechanisms, weights for aileron flutter prevention, wing tip wheels, etc. These were not equipped in the 1/5 model. There also applied material changes (e.g., the spar webs were made of plywood instead of balsa).*

> *From this painful failure, I keenly realized the necessity to develop a method for accurately estimating the final weight of a model airplane at the initial stage where only three views were available*
>
> *Later I developed a formula for estimating RC aircraft weight as below:*

$$W = 2151 L^{-0.11400} b^{-0.76204} S^{1.75388}$$

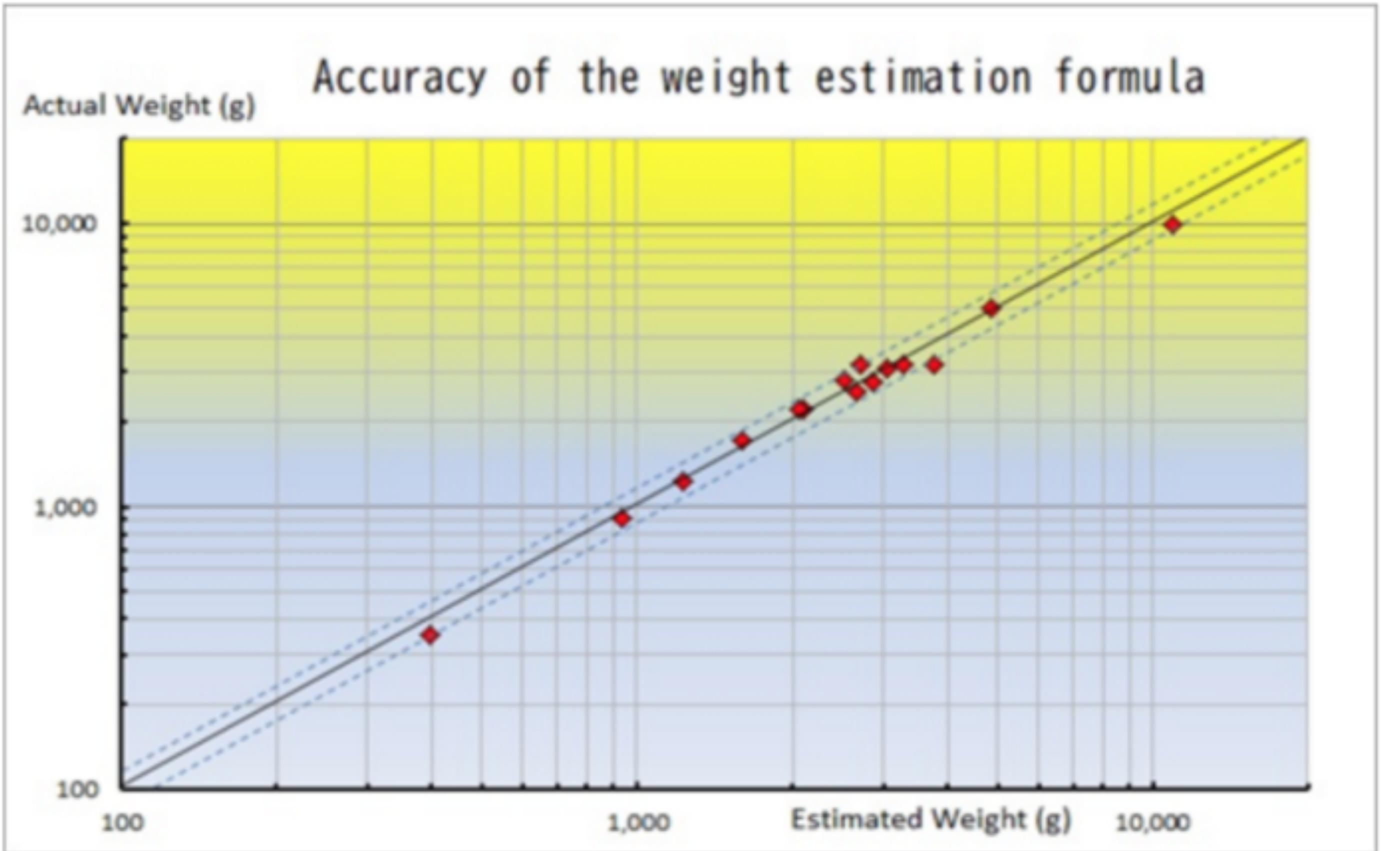
where, L is fuselage length in mm

b is wing span in mm

S is wing area in dm^2

W is weight in g

This formula estimates RC aircraft's total weight(all-up weight) with mean error of 8.7%.

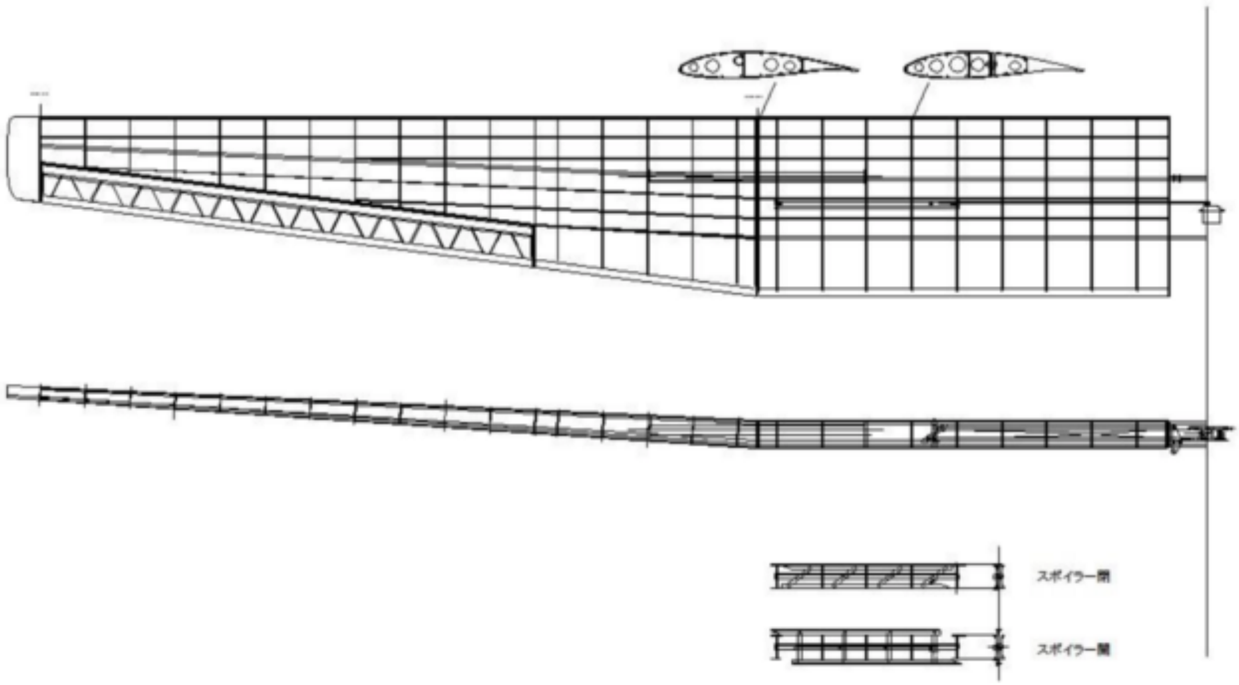


Start Of Design and Manufacturing

The basic concept is also settled, and it is the actual detailed design and production stage.

Main Wing Structure

This is the main wing composition of the 1/3 model designed in Figure 5.



Drawing 5: Main wing structure

The main wing consists of a center wing and two outer wings. They are connected by a carbon pipe with an outer diameter of 20mm, an inner diameter of 16mm, and a length of 480mm. The carbon pipes are supported by thin aluminum tubes with a thickness of 0.5 mm. At first, I could only find aluminum tubes with a thickness of 1 mm, so I bought them and proceeded with the work. However, when I was looking around my workshop, I saw a spare part for the tail boom of a RC helicopter. I measured the inside diameter and it was exactly 20mm! The thickness is also 0.5 mm, which is perfect for this design. This cut the weight in half.

The main spar passes through the thickest part of the wing, about 35% from the leading edge. The center wing has 6×4 carbon square pipe (6 mm square in outer dimension with a 4 mm diameter cavity inside) as the flange and 1.6t plywood web, and the outer wing is made of 5×4 carbon square pipe as the flange. These spars take most of the bending load and the shearing force. The strength calculation which will be shown later told that the main spar could be made of thinner flange, but slightly thicker one was used to ensure rigidity.

The auxiliary spar runs at about 67% of the wing chord. The structure is the same as that of the main spar, but the flanges are slightly thinner, and the center wing is made of 5×4 and the outer wing is made of 4×2.8 carbon square pipe. These auxiliary spars are paired with the main spars and transmit the torsional load of the main wing to the fuselage. The area in front of the auxiliary spar is fully planked with 2t balsa to secure torsional rigidity.

The rib spacing is 100 mm, which is rather wide, so to prevent the plank from yielding, four stringers (two on the top and two on the bottom) are used between the leading edge and the main spar, and same numbers of stringers are used between the main spar and the auxiliary one to increase the rigidity of the plank. The stringers are made of 2×5 balsa bars. In the actual model, auxiliary ribs are placed between the ribs between the leading edge and the main spar, instead of stringers, to maintain the critical wing shape around the leading edge. The reason why I did not adopt this method is that I had installed auxiliary ribs on a previous model, but it was difficult to accurately position them within the short distance between the spar and the leading edge. I had a hard time securing the parallelism of the upper surface of the wing with the auxiliary and main ribs. Unless a positioning jig is provided, it is difficult to accurately position the auxiliary ribs.

Most of the ribs on the center wing are made of 3t balsa, while the outer wing is made of 3t and 2.5t balsa. The mating surfaces of both wings are made of 2t hard balsa, and the innermost ribs of the center wing are covered with 1.6t protective ribs made of plywood.

The outer wing is tapered, so the ribs become smaller as they move outward. At first, I thought it would be easy to draw this proportionally because of the CAD system, but when I actually drew it, I realized that it would be troublesome. The theoretical airfoil has a sharp trailing edge, but if it is left as it is, it will easily dent when the model is hit, so it is necessary to add about 2 mm of thickness. This thickness must be constant regardless of the taper. This means that the airfoil must be modified for each and every rib.

In addition, the outer wing has a twist of 1°. Since the size of the twist on the actual aircraft is not known, this angle was set for the time being. The ribs have to be twisted gradually, but the troublesome part is the spar. If the spar is twisted at the same time as the ribs, the flange made of carbon pipe will be twisted. The carbon pipe has high torsional rigidity, so when the wing is removed from the jig after the assembly is completed, it is expected to be twisted back and the wing will be distorted. In order to avoid this, the ribs are placed in a gradual twisting pattern, but the spars don't. This required a lot of work. I was reminded that I should not underestimate anything.

Production Part 1: Spoiler

I started fabrication at the end of March 2018, starting with the parts for which drawings were ready. The first part to be fabricated was the center wing. This is because it is easy to fabricate since it has constant chord without taper, and also because I wanted to see how big the center wing with 400mm chord length and 2,000mm span actually is.

The spoiler is built into the center wing, so I started with the spoiler. The photo below shows the spoiler parts before assembly.

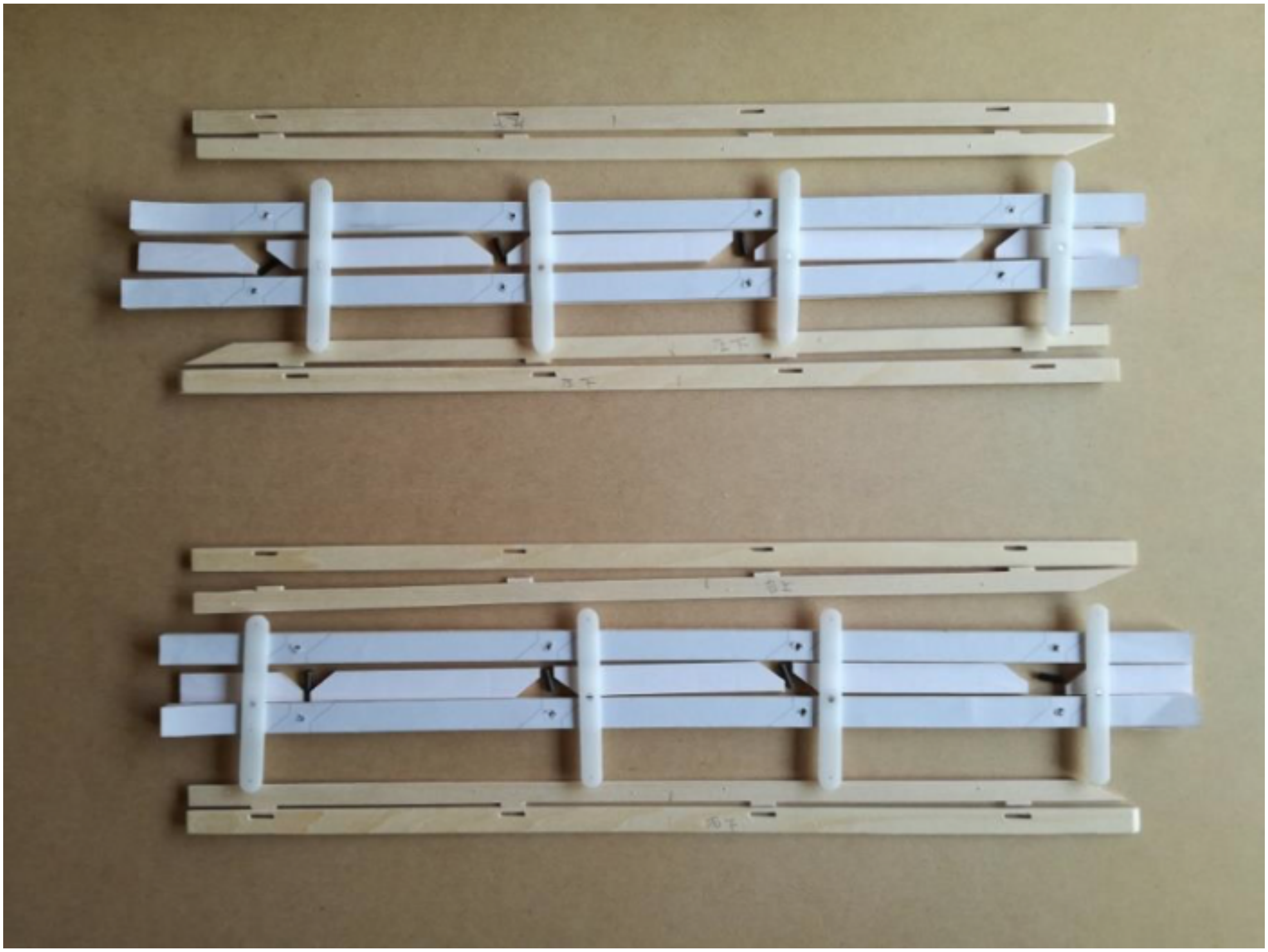


Photo 5: The spoiler parts that I started to build first.

The spoiler protrudes from the upper and lower wing surfaces of the center wing. 1.6mm plywoods are attached to the top and bottom of a 2mm thick acrylic stay to form a T-shaped drag plate, and the center of the stay is sandwiched between two 4mm balsa bars to make the entire structure move in a linkage fashion. The short bars cut diagonally are glued between the 4mm balsa bars to define the working range of the spoiler. Two pull-pull wires are attached to the innermost stay, with that the spoiler is operated by a servo.

> ***Mistake 2:*** *Actually, the structure is so simple that I underestimated it and made a mistake right away. I tried to move the assembled spoiler by hand, but it would not retract at the designed height. It protruded slightly from the upper and lower surfaces of the wing. I tried to fix it, but the*

> *structure is not accessible for modification.*

As I was trying to figure out the cause of the problem, I realized that the width of the acrylic stay was not accurate. In the process of making the acrylic stay, the width of the stay was not accurate by a few tenths of a millimeter. The working range of this spoiler is determined by the contacts between the acrylic stays and the short balsa bars cut diagonally. I was able to cut out the balsa bars accurately in one shot, but I had to cut the acrylic stays a little larger due to the nature of the material, and then file them down to get the right size. I ended up filing the acrylic stays a little larger than the drawing dimensions, so they came into contact with the balsa bars at a smaller angle than on the drawing, and could not be stored properly.

This was a shameful mistake because I drew the plans myself. I ended up rebuilding the spoiler.

> ***Mistake 3:*** *The design of the spoiler turned out to be the biggest failure in the development of this aircraft, as I found out in the flight test after completion. The amount of protrusion of the spoiler was insufficient.*

I thought if the spoiler protruded even a little from the surface of the wing, the air flow would be disturbed and the drag of the main wing would increase significantly, which would have a spoiler effect. Therefore, I didn't pay much attention to the amount of protrusion, and designed the spoiler protrusion of less than 12mm without measuring the actual aircraft's protrusion.

In fact, I learned later that the spoiler not only increases the drag of the main wing, but also acts as a brake with its own drag to reduce the speed of the aircraft. In order to do this, the spoiler needs to protrude far from the wing surface, out of the boundary layer. The spoiler I designed worked well to adjust the descent angle due to the increased drag of the main wing, but it turned out to be insufficient to control the landing speed due to the poor braking effect .

When I presented this model to Mr. Kimura, who owned the actual model, after its completion, he immediately pointed out the lack of spoiler protrusion. I regretted that the spoiler protrusion should have been twice as large as it was, but it was too late.

> ***Lessons Learned 1:*** *Eliminate your own assumptions and do thorough research if you lack knowledge.*

*This is the first part in a series. Read the **next article** in this issue, return to the **previous article** in this issue or go to the **table of contents**.*