1/3rd Scale Mita Type 3 Production Notes

The fifth part of a multi-part series.

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You may want to read the fourth part of this series before proceeding to this article. Also if you prefer, you can read this article in its original Japanese.

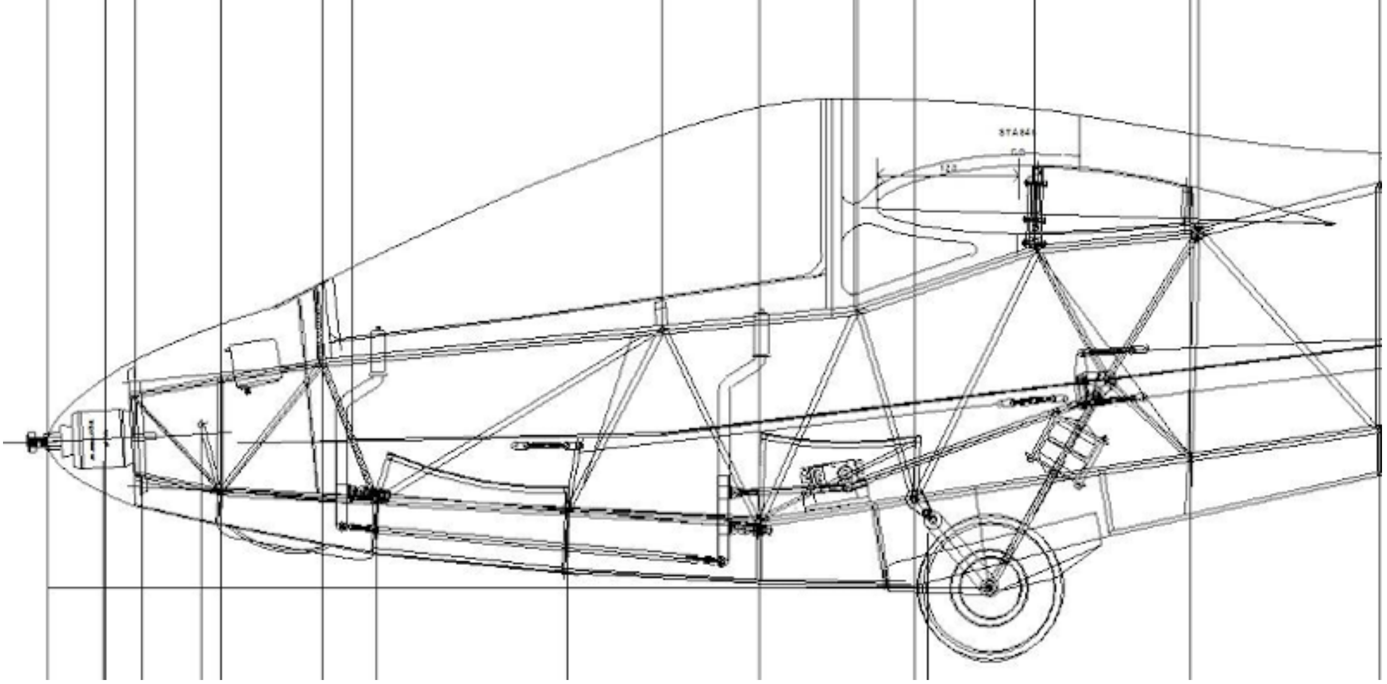
Fabrication Part 16: Elevator Control System

Now that the control stick gimbal system was completed, I made the elevator control system connected to it. During the fabrication process, it was discovered that there was a design error in the gimbal system. I modified the gimbal system and fabricated the elevator control system.

Overview of the Elevator Control System

The elevator control system of the actual aircraft consists of a push-pull rod extending from a hinge mounted above the gimbal of the rear control stick, which passes under the rear seat and connects to a bell crank mounted on the trapezoidal truss structure that holds the main landing gear. Two wires extend from each end of the bell crank and connect to the bell crank under the horizontal tail. The wires connecting the two bell cranks are crossed for structural reasons. In other words, the wire extending from the top of the front bell crank connects to the bottom of the rear bellcrank, and the wire from the bottom of the front bell crank connects to the top of the rear bellcrank. The connection from the bellcrank under the horizontal tail to the elevator is as seen in drawing 14 and photo 40 in the 3rd edition (June).

The push-pull rod that passes under the rear seat is refracted for mounting reasons, as shown in drawing 25. Therefore, in the 1/3 model, the rod is divided into two parts at this point, and a servo is inserted in between to move both the elevator and the control sticks.



Drawing 26: Elevator control system.

In the process of building the elevator control system based on this drawing, I discovered a design error in the gimbal mechanism.

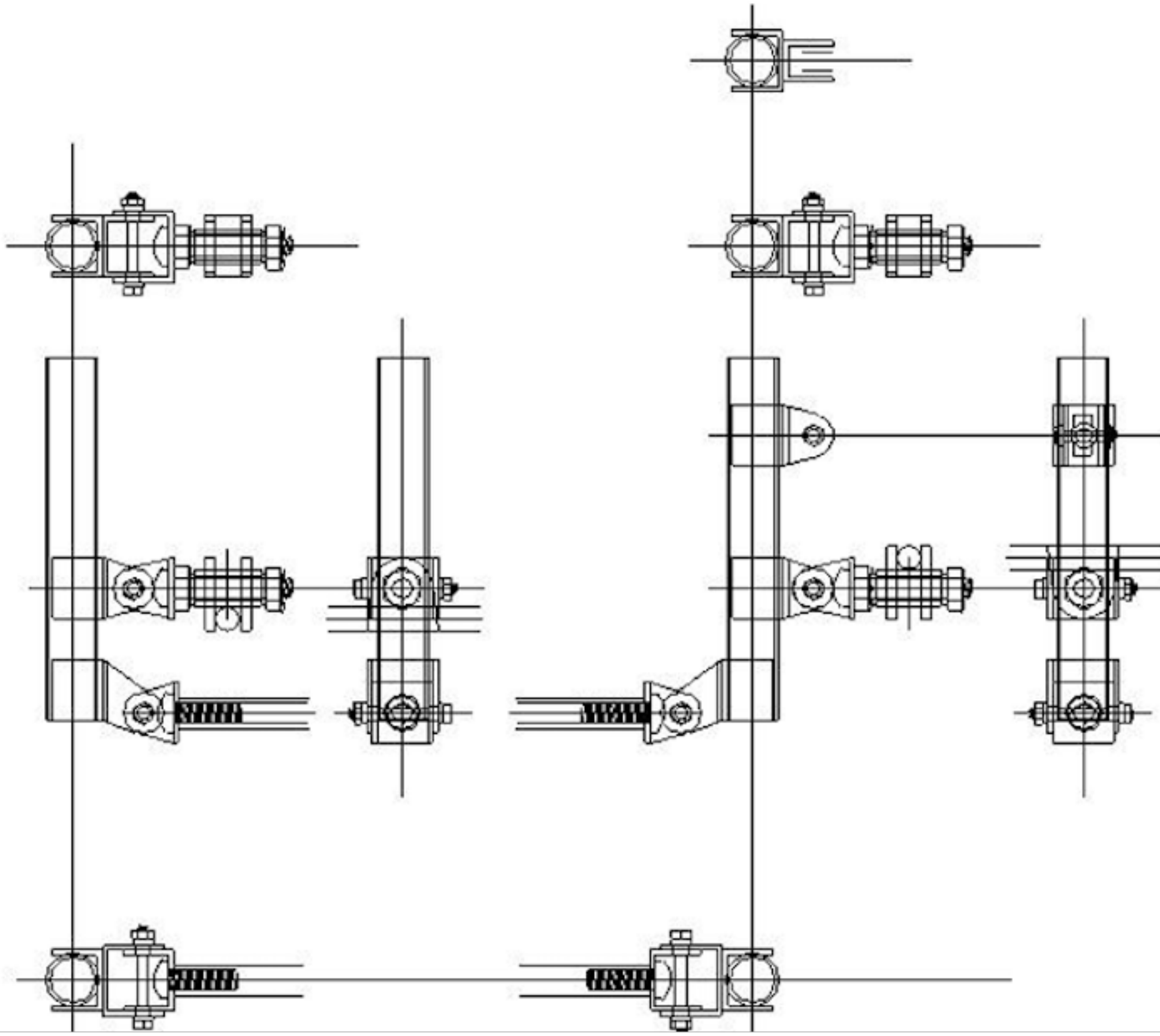
> ***Mistake 8:*** *Gimbal mechanism design error*
>
> *There were two mistakes. One was the type of the rod end for the push-pull rod mounted on top of the rear gimbal. This was supposed to be a rotating type with a bearing. However, the push-pull rod also swings left and right as the aileron is operated. But, since the other end of the rod is attached to the servo, there is no way to move left or right. In other words, the rod ends attached to both ends of the push-pull rod must be spherical bearing type to allow such movement. I redesigned the rod ends and replaced them with spherical bearing rod ends used in RC helicopter control systems.*

> *The second mistake was the attachment mechanism of the connecting rod that connects the front and rear gimbals. It was found that the mounting rigidity of the gimbal and connecting rod was insufficient, causing a large tilt angle difference between the front and rear control sticks when the aileron is operated.*

In a normal tandem control system, the aileron axles of the front and rear gimbals are connected with a single pipe, which transmits the aileron steering force as a torque tube. However, the aileron axles of this aircraft are not connected. Therefore, the connecting rod, which originally links the elevator operation, also plays a role in linking the aileron operation. For this reason, the connection between the connecting rod and the gimbal must have sufficient rigidity in the left-right direction, but the simple rod ends connection I had adopted resulted in insufficient rigidity. By examining the actual aircraft again, I found that the rod was connected with very tough metal fittings as shown in photo 81.

Gimbal Modification

Based on the above consideration, I modified the gimbal drawing.



Drawing 27: Modified gimbal mechanism.

The coupling parts with the connecting rod have the same structure as the actual machine. Photo 87 shows the gimbals modified according to the drawing.

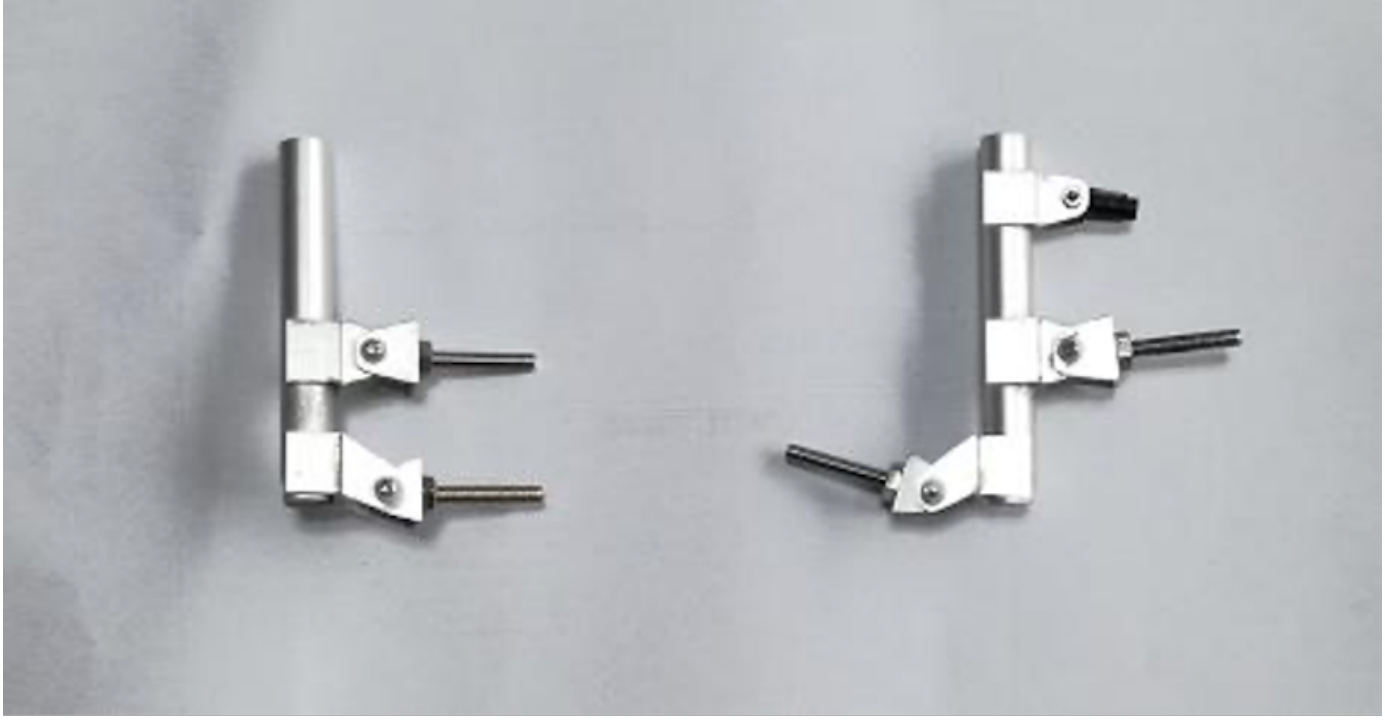


Photo 87: Gimbal mechanisms after modification.

These modified gimbals were attached to the fuselage, and this time, it is very rigid and there is no angular difference between the front and rear sticks when they are tilted left and right. I also confirmed that the rear gimbal and elevator servos are well connected.

Elevator Control System Installation

Now that the gimbal mechanisms have been modified, the elevator control system has been installed. Photo 88 shows the connection between the elevator servo and the front side bellcrank.

Photo 88: Elevator servo and front side bellcrank.

Next, photo 89 is an enlarged photo of the front side bellcrank. The picture is out of focus, but you can see two turnbuckles on the bellcrank to adjust the wire tension. The turnbuckles were made from a Φ5 brass rod by Mr. Takamura who has a mini-lathe.

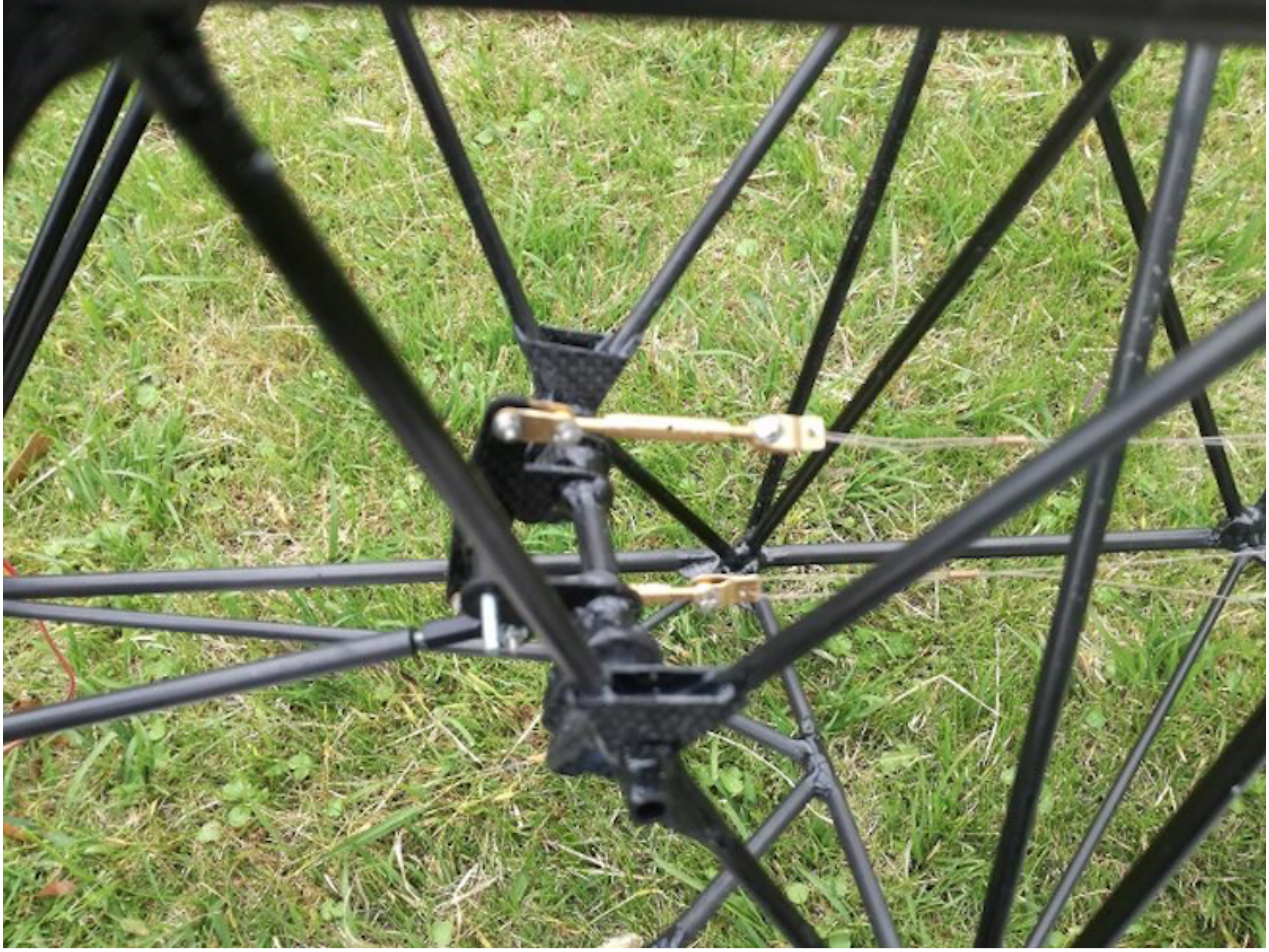


Photo 89: Enlarged view of the front bellcrank.

Photo 90 is a rearward view of the inside of the fuselage.

Photo 90: Left, rearward view of the inside of the fuselage. Right, looking backward inside the fuselage.

A wooden stay is attached in the middle of the rear fuselage to avoid the crossed wires from rubbing against each other and to prevent the wires from vibrating.

Finally, here are the details of the rear bellcrank.

Photo 91: The rear bellcrank.

The wires are still temporarily fastened.

Fabrication Part 17: Center Wing Plank and Wing Fuselage Joining Hardware

At the end of October 2018, it became much cooler and I could sand balsa outdoors. So I started to plank the center wing, which I had postponed since before summer. At the same time, I made the wing-body joint fittings.

Planking of the Center Wing

Planking is done with 2mm thick balsa boards. The center wing is completely planked between the leading edge and the rear spar to secure the airfoil shape, and also plays a role in securing the torsional rigidity of the wing by forming a large D-shaped spar in unison with the rear spar web. The distance from the leading edge to the rear spar is about 280 mm on the upper surface of the wing. Normally, balsa sheets are sold cut into 80 mm widths, so it is necessary to join four sheets together. The process of piecing the balsa boards together is rather troublesome. I looked for a wider board, and found that the boards sold at World Models were 95mm wide, so I decided to use them. Four boards were made of three pieces of balsa, each 900 mm long, joined together. I lightly sanded the surface side of the boards to remove any unevenness.

Planking started with the undersides. The procedure is as follows: lay a thin polyethylene sheet on the assembly jig to prevent adhesion, place a planking board on top of the sheet, put the rib assembly on top of the board, press it down, and apply low viscosity CA to the key points. Since the ribs and the assembly jig were originally one piece, and they were cut out, they fit together quite nicely even with a 2mm plank material in between.

After gluing is completed, take it down from the jig and cut out the spoiler part from the inside and the extension cord is inserted for the aileron servo. I set the cord near the leading edge to avoid any tail-heaviness. Photo 92 shows the left center wing with the lower plank completed.

Photo 92: Left side center wing with the lower plank completed.

Next is the upper side plank. The upper spoiler groove cannot be cut out from the inside after planking, so carefully align and cut it out beforehand.

Image 93: Aligning the upper plank material.

The next step is to place the wing on an assembly jig placed on a thick plate, and apply titebond to the ribs, spars, and stringers. The upper plank is inaccessible from the back, so instant adhesives cannot be used. After making sure that there is no residue of the titebond, the plank material is carefully positioned and then covered. Next, cover the plank with a few thin cypress sticks, hook the rubber band to the nails on the side of the base plate, and press down the entire assembly onto the jig.

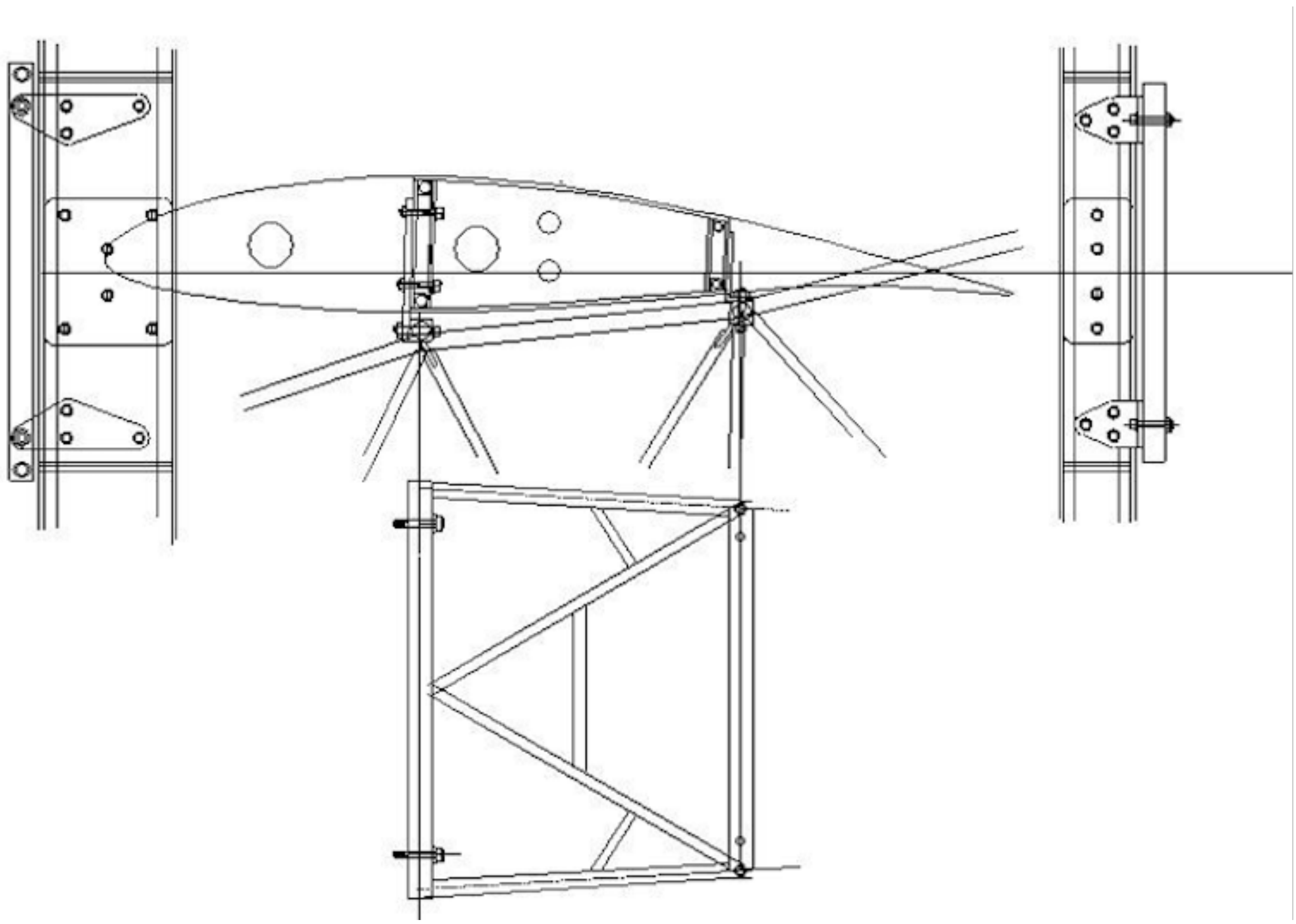
Image 94: Upper plank of the center wing.

This is to make sure that the plank material adheres to the ribs and spars. When the glue dried, thin 15 mm wide bars were cut from a 4 mm thick balsa board and attached to the front edge. Then,I sanded and shaped the leading edge.

Through this planking work I got a lesson that I should pay attention afterwards. This 1/3 model is quite large, and the area of the titebond application for the upper plank is also very large. The instruction manual says that the titebond should be applied within five minutes, but it took a little more than five minutes to apply it. Therefore, the surface of the applied titebond was just about to start drying. In the future, the outer wing will be planked over a much larger area, so it must split the plank board into two and separate the work.

Fabrication of the Wing-Body Joint Fittings

Next, I started to make the fittings to attach the center wing to the fuselage. Here is the drawing of this part.



Drawing 28: Wing-body joint.

The fittings extending down from the front spar are attached to the bolts protruding forward from the square crossbeam running across the left and right sides of the fuselage, the same as in the actual model. However, the fittings between the rear spar and the fuselage are different from the actual model. In the actual model the fuselage is connected to the rear spar by the fittings as shown in photo 95.

Photo 95: Fittings of rear spar and fuselage of actual model.

To make these fittings, you need a milling machine, but even my clubmate who is good at metal working only has a mini-lathe. So I changed the fitting to an aluminum L-shaped channel, which is available at home centers.

Photo 96 shows the fittings I made.

Photo 96: Wing fuselage joint fittings: top, front side; bottom, rear side.

The front fittings were cut from 3mm thick hard aluminum that was used for the main landing gear of a discarded RC fixed wing, and the rear fittings were cut from 2mm thick L-shaped channel.

These fittings were first attached to the fuselage, and then the center wing was placed on the fuselage to find the mounting position. Photo 97 shows the final fuselage and center wing joined by the fittings.

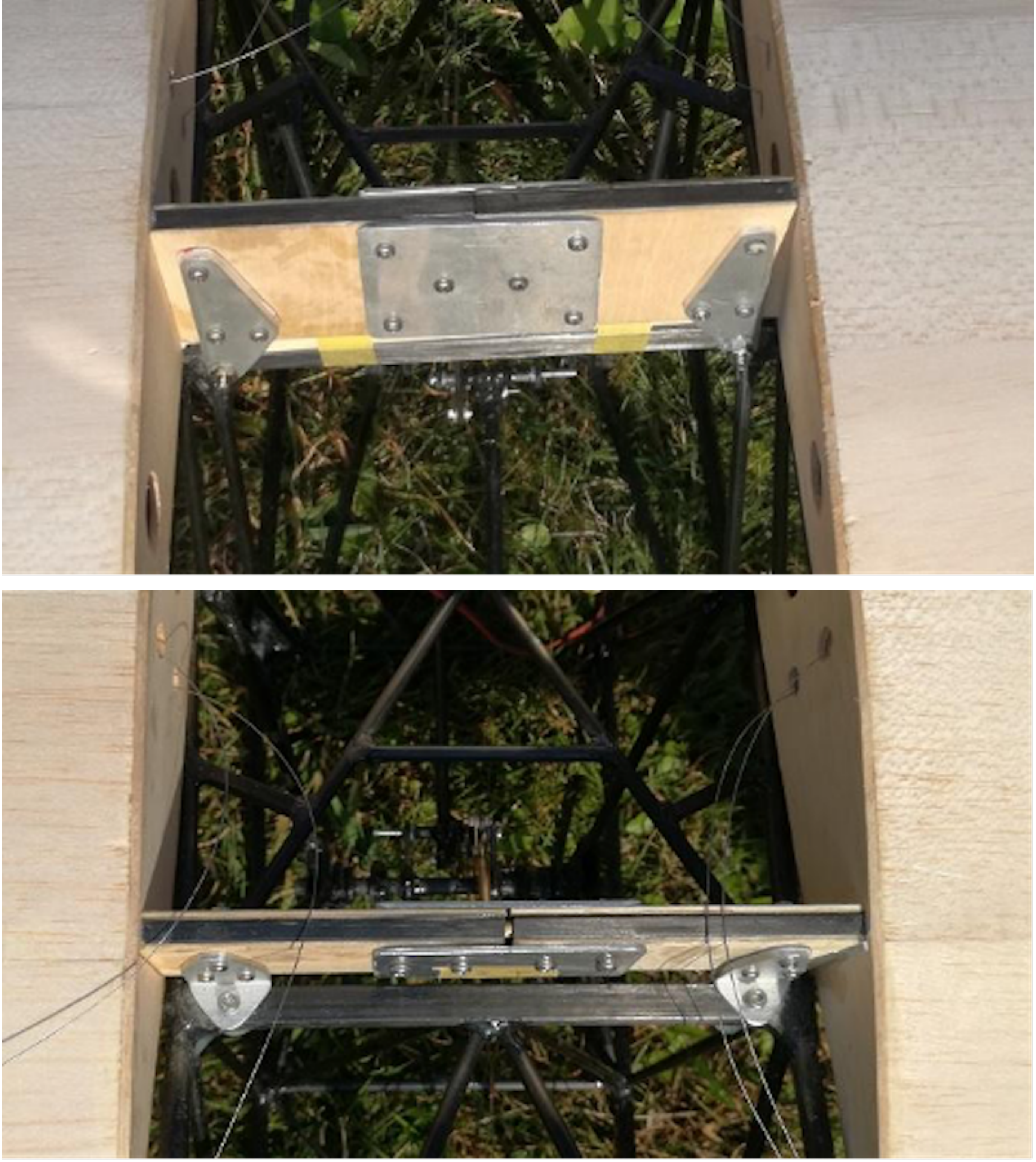


Photo 97: Fuselage joint test: left, front side; right, rear side.

Actually, it was a little difficult to reach this state after making the fittings. At first, I measured the squareness of the main wing and fuselage with the front side fittings. I stretched a string between the wing tip and the end of the fuselage and compared the length of the string between the right and left sides. The result showed that the right side string was about 13mm longer than that on the left side. This means the main wing is attached to the fuselage slightly yawed to the left.

The reason for this is that the crossbeam on the fuselage to which the front spar is attached is slightly yawed to the left of the aircraft center axis. In fact, it was extremely difficult to secure the right angle of this beam when installing it. The fuselage is tapered backward, so it is difficult to find the center axis of the fuselage. The drawing showing the center axis of the fuselage is pasted on the bottom of the fuselage assembly jig, but there is a space of 200mm between the drawing and the crossbeam. This is the reason why the cross beam was attached at a slight angle. To correct this problem, 0.5mm shim was inserted between the front right side fitting and the center wing spar web. As a result, the main wing is now attached to the fuselage at right angles.

Next, I installed the rear fittings with the front fittings in place. The left side fit perfectly, but the space between the right side fitting and the rear spar web opened up by about 0.5mm. This was due to the shim inserted in the front fitting. I had no choice but to insert 0.5 mm shim here as well.

Spoiler Servo Installation and Adjustment

Now that the center wing is attached to the fuselage, the spoiler servos are installed on the center wing.

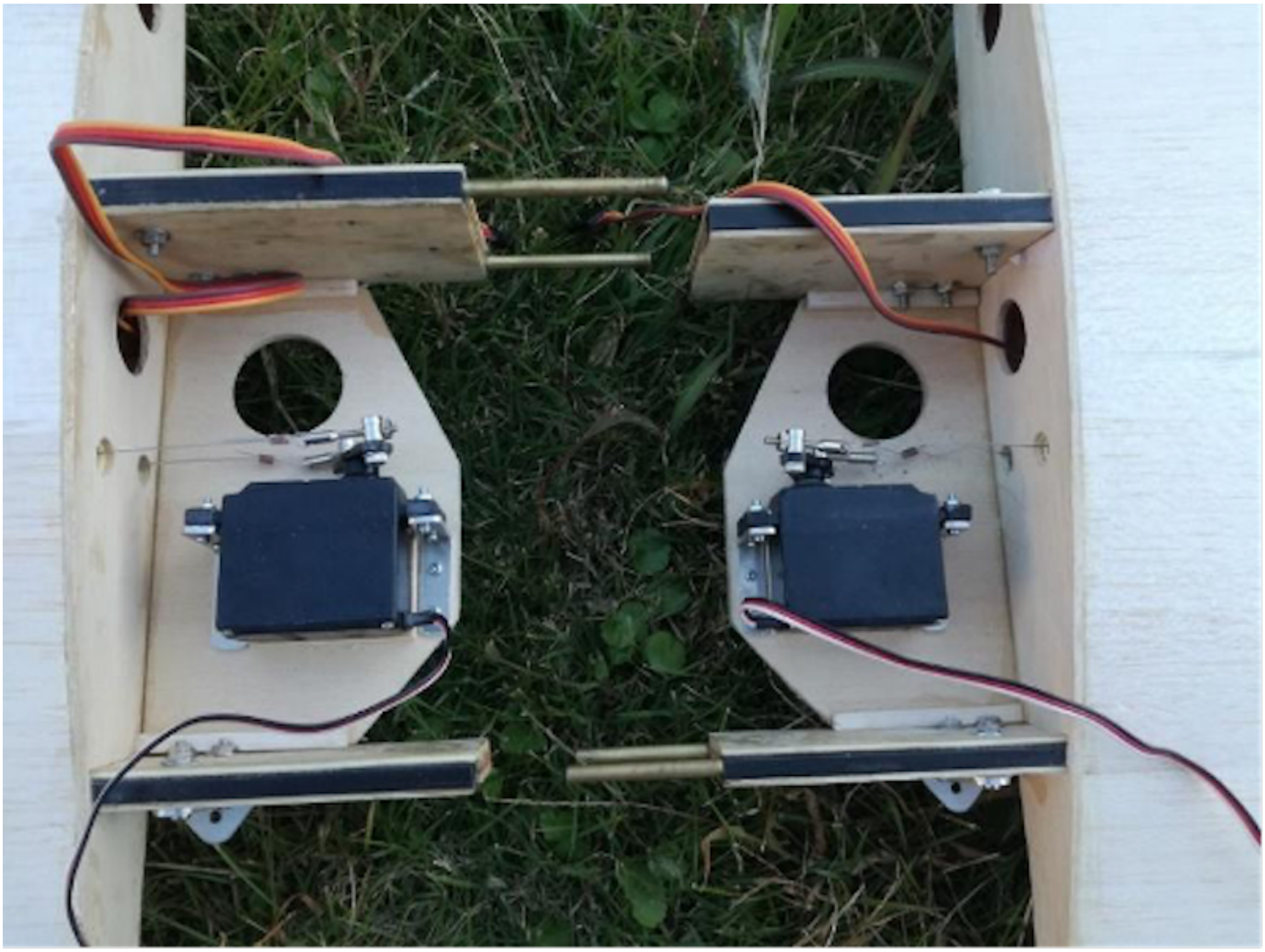


Photo 98: Spoiler servos installed.

Then I adjusted the spoilers. Thin balsa sheets are attached to the tops of the spoiler. These balsa plates are slightly protruding from the surface of the wing. They are shaved to make a smooth contour with the wing surface when the spoilers are closed.

If you operate the servo in the direction of spoiler closing, the servo will jitter at a certain position. This is because the servo is trying to close the spoiler even though it is already closed. This condition always occurs in a spoiler model such as this one, which does not have a limit switch.This condition consumes unnecessary power and is not good for the servo. In addition, if it is not done properly, the wire may break. So, I installed a servo tester as shown in photo 99 and found the position just before the servo starts to jitter. This is the position where the spoiler is fully closed. Then I shaved the balsa attached to the top surface so that the spoiler surface matches the wing surface. This resulted in a smooth wing surface with the spoiler closed, as shown in the photo 100.

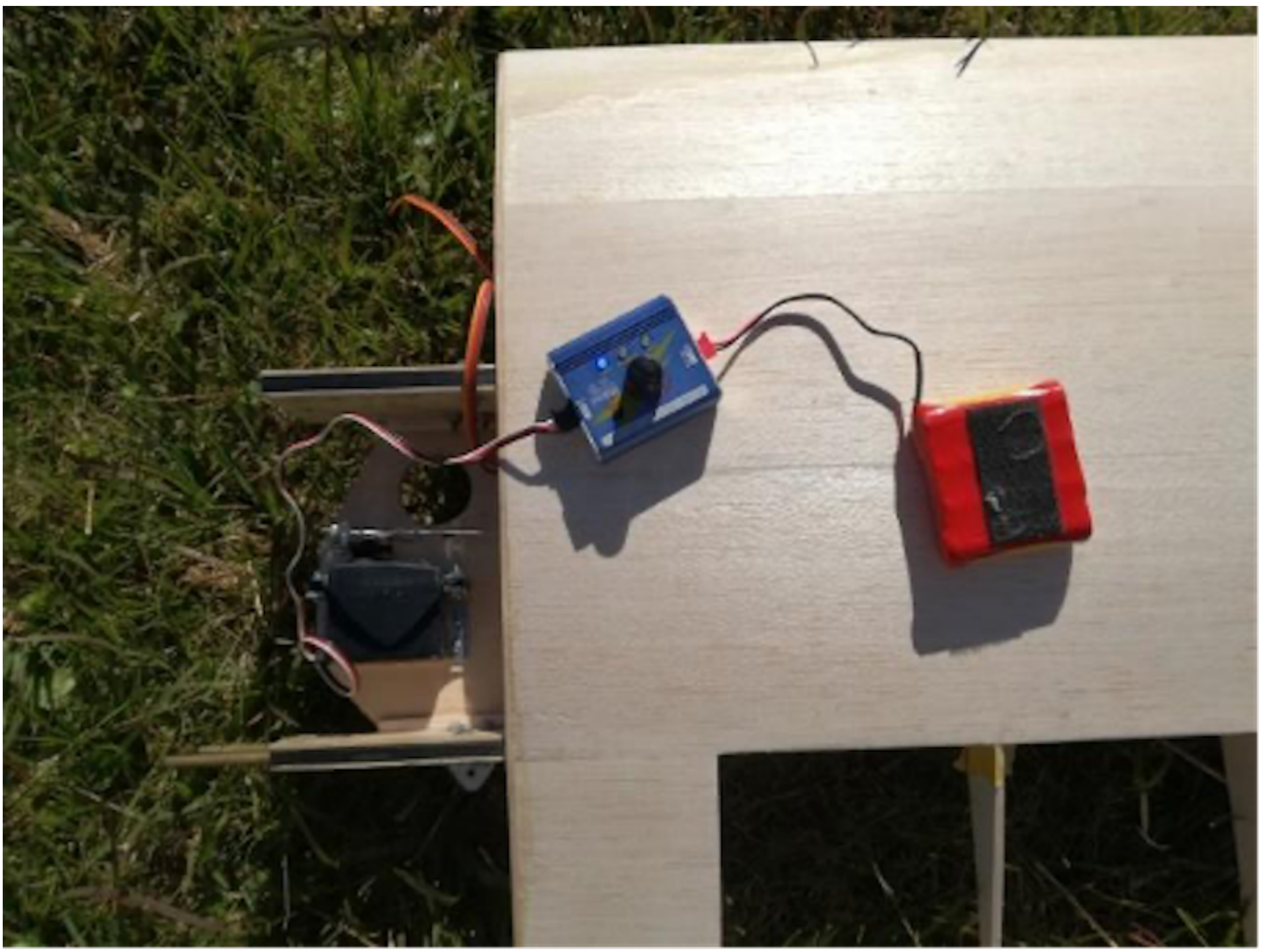


Photo 99: Adjusting the spoiler servo with a servo tester.

Photo 100: Spoiler closed.

Next, I turned the knob of the servo tester in the opposite direction to check the spoiler opening status.

Photo 101: Checking the spoiler open state: left, upper side; right, lower side.

At this point, I thought it worked well, but in fact, the amount of spoiler protrusion was too small, as described in Mistake 3.

Completed Center Wing Assembly

This is the center wing assembly completed. Only the covering remains.

Photo 102: Finished center wing.

The left side is 717g and the right side is 737g. The right side is 20g heavier than the left. This is probably due to the weight variation of the plank material and the difference in the amount of epoxy adhesive used, which was applied in large quantities around the aluminum tube of the wing connecting pipe receiver.

Performance Prediction

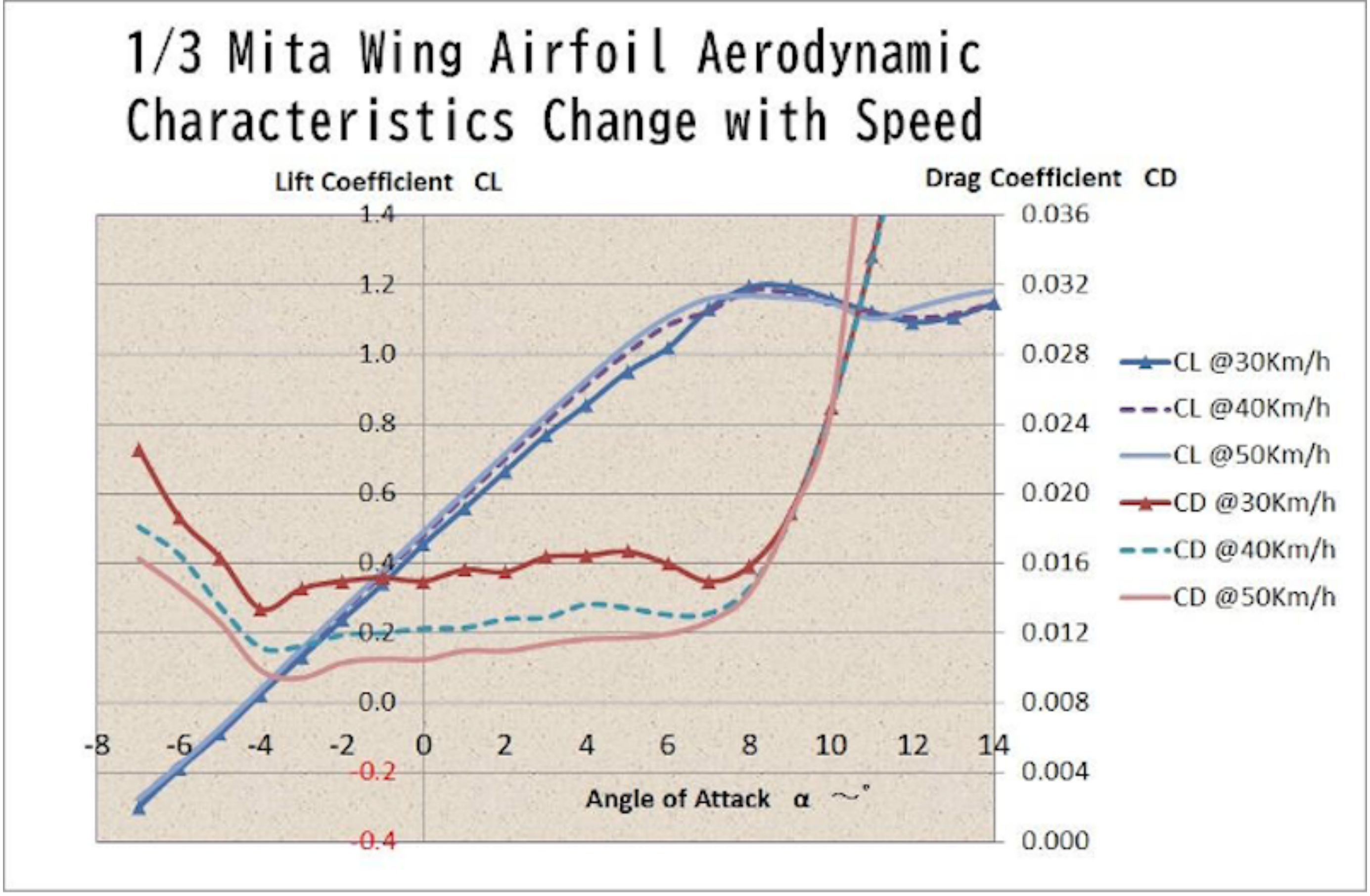
Due to a flaw in the way the target weight was determined, a significant weight increase over the plan is inevitable. As a result, I was wondering how much the performance of the glider will change. Therefore, I made a calculation to predict the flight performance of the 1/3 Mita. At the same time, I compared the performance of the 1/3 Mita with that of my 1/5 Mita.

Performance Estimation Method

The performance estimation was done by describing the longitudinal forces and moment balance formula of the aircraft in EXCEL, referring to “Introduction to Aircraft Dynamics” by Kanichiro Kato et al published by the University of Tokyo Press. In other words, the calculation was repeated by changing the descent angle, aircraft attitude angle, and elevator angle until the aerodynamic forces (lift, drag, and pitching moment) acting on the main wing, tail, and fuselage at the specified speeds were balanced by gravity at the center of gravity.

Aerodynamic Characteristics of Airfoil

I paid special attention to the aerodynamic characteristics of the airfoil (lift, drag and moment characteristics) in this performance estimation. In normal aircraft performance calculations, the aerodynamic characteristics of the airfoil are treated assuming that the non-dimensionalized lift coefficient CL, drag coefficient CD and moment coefficient CM do not change with flight speed. However, as discussed in the basic concept №4, the aerodynamic characteristics of the wing airfoil changes significantly with Reynolds number, Re, in the size and flight speed range of this model. Therefore, in this performance calculation, the aerodynamic characteristics of the main wing are given for each Re corresponding to the flight speed, and the Reynolds effect is taken into account. The lift coefficient CL and drag coefficient CD of the main wings at these speeds are shown in the figure below. The Re of this model at speeds of 30 km/h, 40 km/h, and 50 km/h are 193,000, 258,000, and 322,000, respectively.

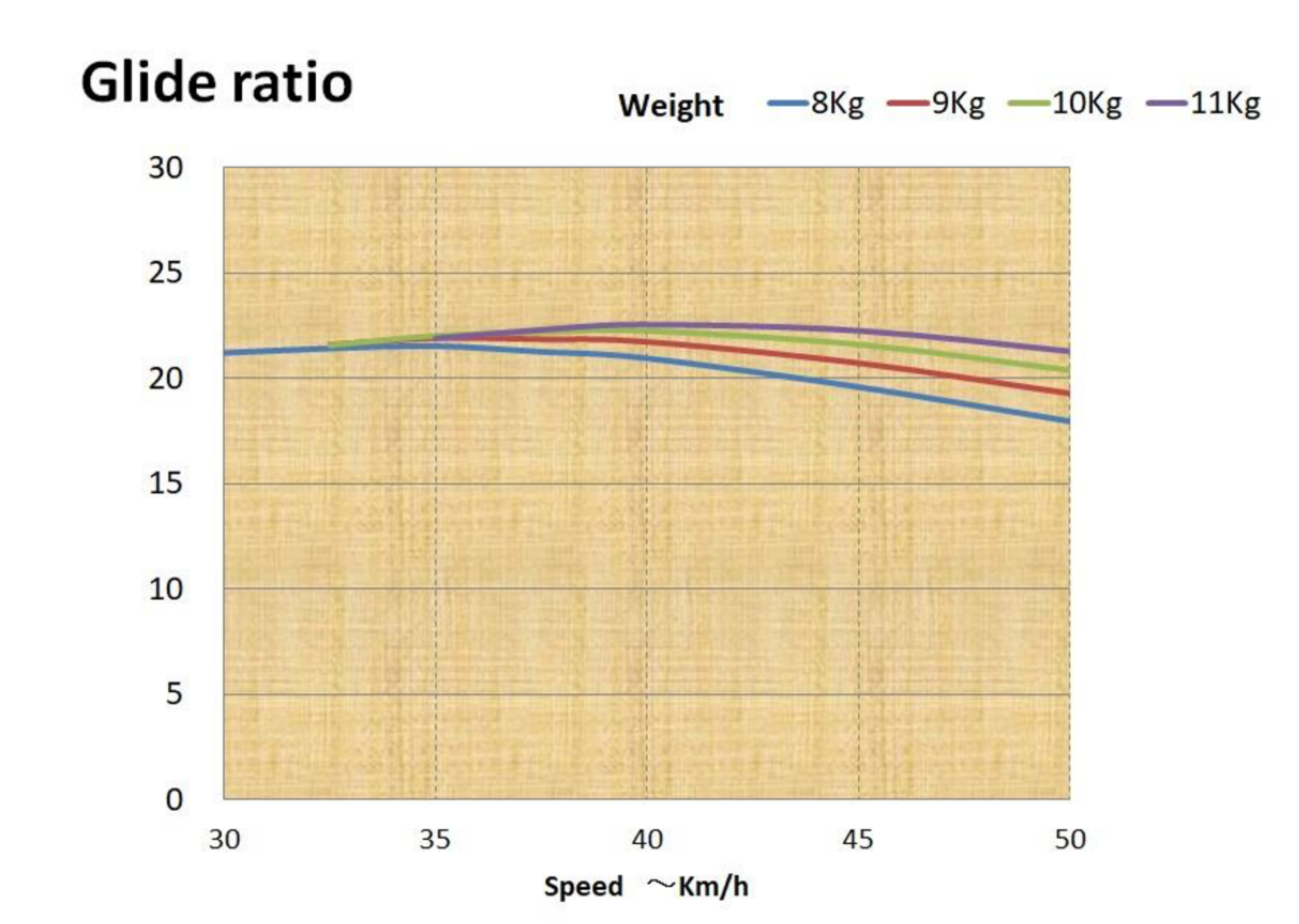


Graph 9: Wing Lift and Drag coefficients change as a function of flight speed.

There is no significant change in the lift coefficients, but there is a significant change in the drag coefficients. It can be seen that the higher the speed, the higher the Re and the smaller the coefficient. Therefore, the gliding performance of this 1/3 Mita also improves as the speed increases. The aerodynamic characteristics of the airfoil were calculated using the XFLR5 which includes the XFOIL, a software program developed at the Massachusetts Institute of Technology (MIT) in the U.S. XFOIL has an established reputation for analyzing airfoils at low Reynolds numbers. I checked the reliability of this software and confirmed it by comparing the calculated values with wind tunnel test data at low Re in advance.

Estimated Performance of 1/3 Mita

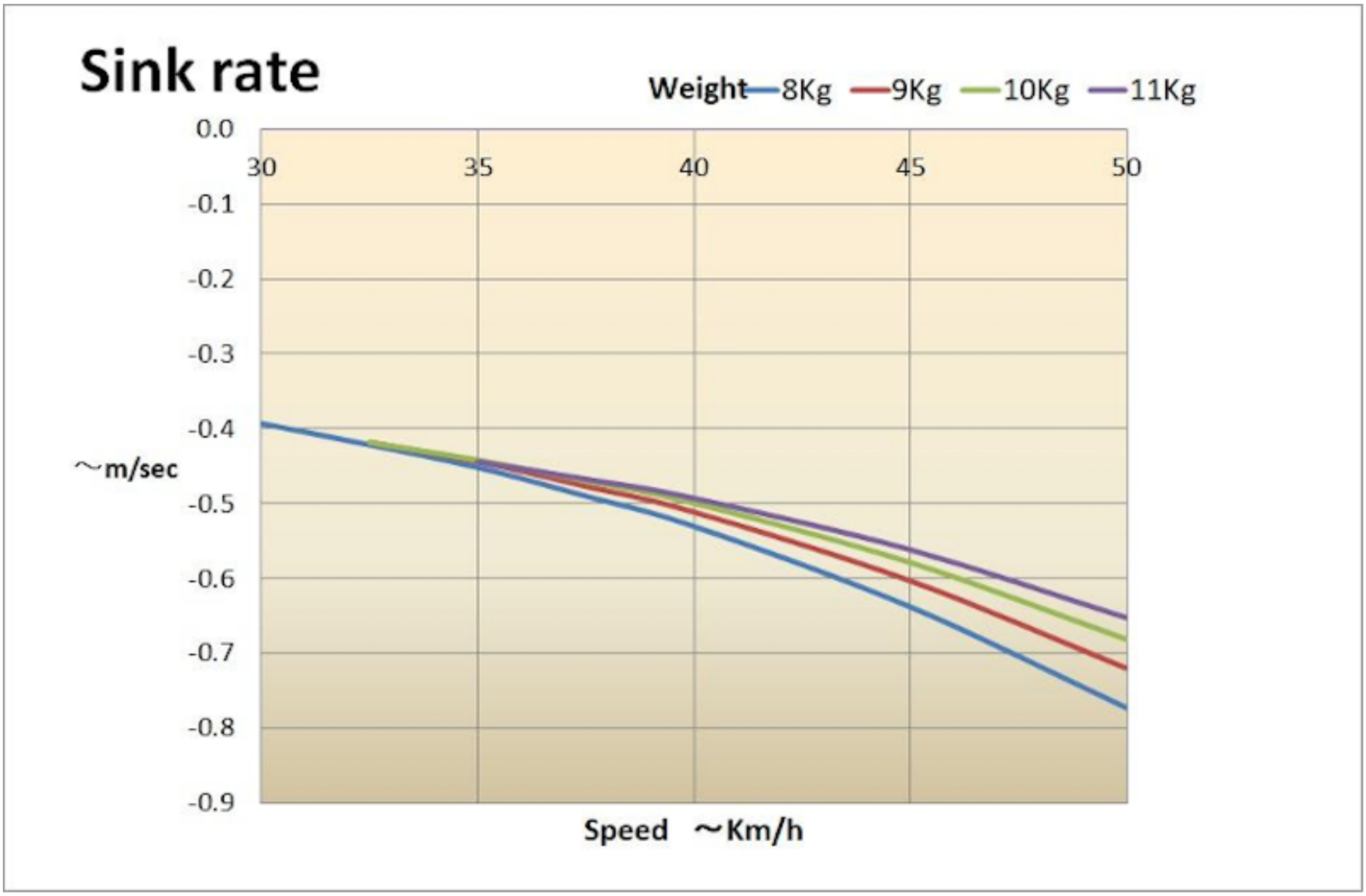
With these preparations, I estimated the performance of the 1/3 Mita. First, below is the glide ratio, which is the most important performance index for a glider.



Graph 10: Predicted glide ratio of the 1/3 Mita Type 3 Revision 1.

The calculation was conducted with a weight range from 8 Kg to 11 Kg in 1 Kg increments. The maximum glide ratio is expected to be slightly over 22. As the weight increases, the maximum glide ratio increases, but the speed at which the maximum glide ratio is achieved also increases. The glide ratio of a normal glider drops more rapidly above the best glide ratio speed, but with this glider, the drop is slower due to the Re effect of increased speed. Therefore, it seems that a good glide ratio can be obtained over a relatively wide speed range.

Next is the sink rate.



Graph 11: Predicted Rate of Descent for 1/3 Mita Type 3 Revision 1.

The lower the speed and the lighter the weight, the smaller the sink rate will be. The minimum sink rate for a weight of 8 kg is obtained when flying at 30 km/h, and the value is less than 40 cm/sec. The minimum speed at which the curve begins for each weight is different, because the aircraft will stall and can not fly at the lower speed range to the left. Even with a weight of 10 kg, it seems to be able to cut 50 cm per second sink rate.

The minimum sink rate speed is near the stall limit, so I need to increase the speed a little more to fly the scale plane safely. It is interesting to note that the heavier the weight, the lower the sink rate in the speed range where stall does not occur. Therefore, it seems that I don't need to be so nervous about weight increase.

The reason why the sink rate decreases with weight is that the power required to fly the glider during descent is supplied by the decrease in the potential energy of the aircraft.

The decrease in potential energy is given by the product of the weight of the aircraft and the sink rate, so the heavier the aircraft is, the more power it can generate if the sink rate is the same. On the other hand, the power required for flight during descent does not differ significantly depending on weight. The reason is that the power required for flight is consumed by two types of drag: the profile drag and the induced drag, and these drag hardly change with weight.

This is because, as shown in Graph 9, the drag coefficient of the airfoil clearly shows that the increase in the profile drag is negligible even if the angle of attack increases slightly due to the increase in weight. Of course the heavier the aircraft, the greater the induced drag, but it decreases exponentially as the speed increases, so that it becomes a very small value near the best sink speed. Therefore, the increase in potential energy due to the increase in weight is greater than the increase in power required for flight due to the same increase in weight, and as a result, the heavier the aircraft, the less sink rate is obtained.

Comparison with 1/5 Mita

For reference, I also estimated the performance of my 1/5 Mita and compared it with the 1/3.

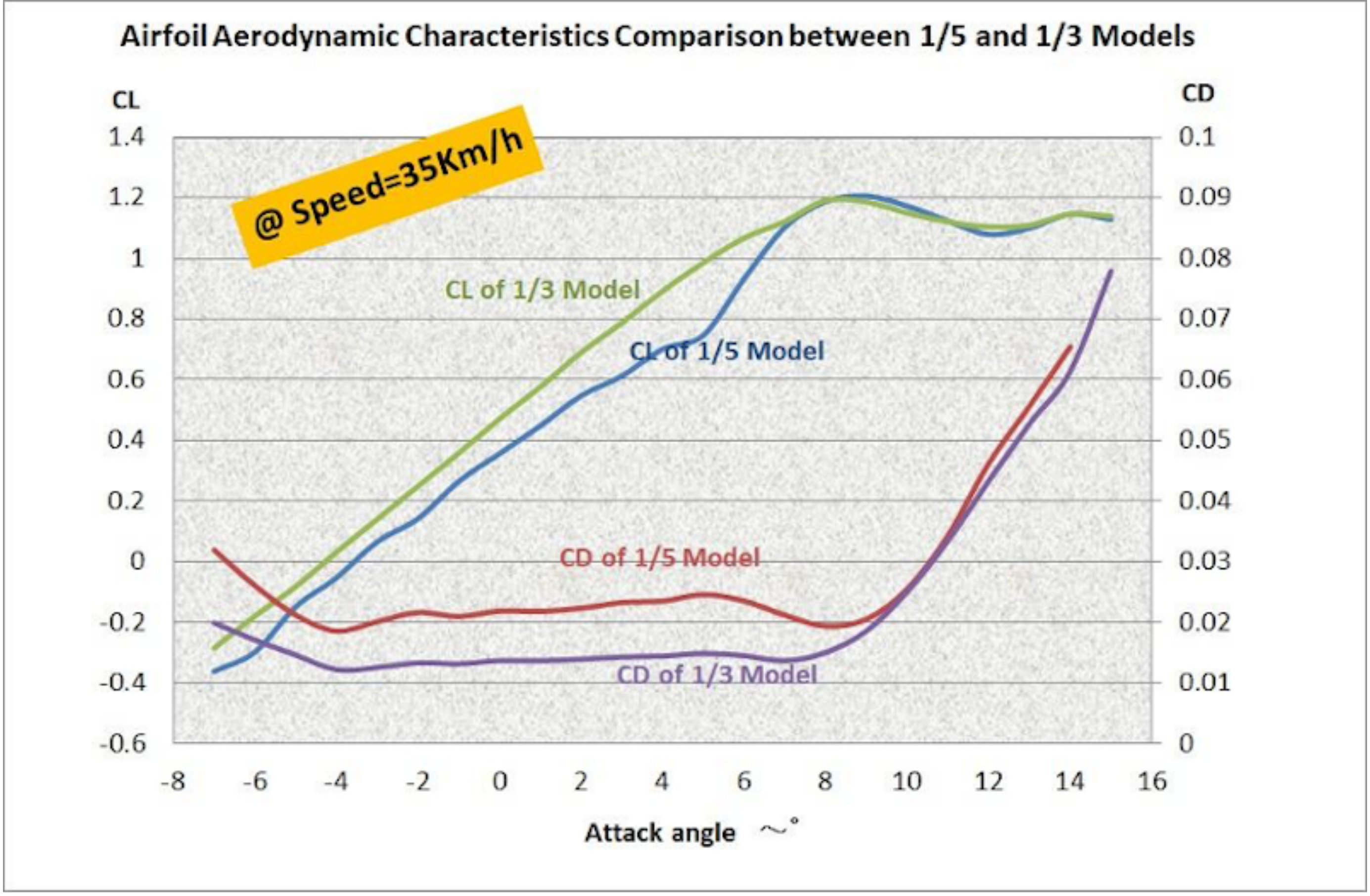
Graph 12: Comparison of glide ratio between 1/3 and 1/5.

Here is a comparison of glide ratios: 1/5 weighs about 2.8 kg, 1/3 weighs 9 kg. The best glide ratio of the 1/5 is only about 17. I am not so dissatisfied with this glide ratio, but the 1/3 is expected to improve it by about 30%.

The sink rate also improves as shown below.

Graph 13: Comparison of the sink rate between 1/3 and 1/5.

The reason for these performance differences is the difference in the aerodynamic characteristics of the main wings due to the difference in Reynolds number between 1/3 and 1/5. Following graph compares the airfoils lift and drag coefficients of the two aircrafts at a flight speed of 35 km/h.



Graph 14: Comparison of 1/3 and 1/5 wing airfoils aerodynamics.

The performance of the actual aircraft is superior to the model because the Reynolds number is even higher. According to the data, the best glide ratio is 30.8, but the flight speed that gives this glide ratio is 80 km/h, which is much faster, and the minimum sink rate is 72 cm/sec because of large wing loading.

From the above estimation, it seems that the flight performance of the 1/3 will be much better than that of the 1/5, and I can expect it to have good floatability. Also, there seems to be no need to worry about the weight increase.

Fabrication Part 18: Outer wing planking

Following the center wing planking, I planked the outer wings.

Planking of the Lower Surfaces of the Outer Wings

The rib assembly of the outer wings were completed at the beginning of August 2018, but the planking work was left until November to avoid the hot and humid summer because a lot of balsa powder flies when sanding the planking material.

I started planking the left lower surface first. Having made a paper pattern, I cut out the plank plate from the balsa board. Next, I laid a polyethylene sheet on the assembly jig, placed the plank plate on it, and put the rib assembly on top of it. But the jig, made of 2.5 mm balsa sheets, had warped considerably over the past three months, so it didn't fit the plank plate and rib assembly perfectly. I fixed it in various ways and when it seemed to have settled down, glued it all together with low viscosity CA. However, I made a big mistake here.

> ***Mistake #9:*** *Planking without noticing the deformation of the outer wing rib assembly*
>
> *At this time, I should have carefully checked the deformation of the rib assembly that has been left untouched for the last three months. But I paid too much*

attention to the deformation of the jig. When the lower surface planking was completed, I looked through the spar from the side and found that the carbon spar flanges, which should be straight, were slightly curved!

Image 103: Deformation of the outer wing spar.

The photo 49 (June issue) taken when the rib assembly was completed showed the spar went straight through. I regretted that I should have checked more carefully before dropping the CA, but it was too late. There was no way to fix it. It was a painful mistake.

After regaining my composure, I checked the effect of the bent spar in connection with the center wing (photo 104).

Normally, the leading edges of the center wing and the outer wing are in a straight line, but the leading edge of this outer wing has a swept back angle of about 0.57°. This is a big mistake for a scale aircraft, but the saving grace is that the outer wing has an dihedral angle, so its leading edge appears to be slightly swept back in most cases. This can also be seen in my 1/5 model (photo 105) where the leading edge was made straight through. Therefore, I decided to leave the wing as it is because it will be almost indistinguishable in appearance and this degree of retraction will have little effect on the flight characteristics.

The above problem was discovered before the right wing planking, so the right wing was intentionally planked with a leading edge swept back angle of 0.57° in order to achieve symmetry. Ideally, the planking work should have been done without delay following the completion of the rib assembly.

> ***Lessons Learned 5:*** *When assembling the wing, proceed to the plank at once. If you leave the rib assembly for a long time, it will be deformed.*

Photo 105: The outer wing always appears to be swept back.

Problem with the Aileron Hinge Was Discovered

When I tested the installation of the aileron after completing the lower surface planking, I found there were steps between the wing and the lower surface of the aileron, which should be smoothly connected. The amount of these steps are different in the span-wise direction, the aileron was attached to the upper side by a maximum of 2mm. This means the aileron cannot function as a frise-type aileron.

> ***Mistake #10:*** *Aileron mounting position is incorrect*
>
> *The cause seems to be the aileron hinges are positioned incorrectly on the rear spar of the outer wing. This is probably due to the fact that the hinges were installed*

> *into the mounting holes drilled by hand without using any positioning jig. I should have carefully checked the positions of the hinges with the aileron attached before they were glued.*
>
> *I had no choice but to remove the hinges and reinstall them, but it was tough work to remove them because the hinges were made of carbon and were tightly bonded to the rear spar web with CA. This is a typical example of a problem that can occur if the work procedure is not carefully considered.*

After a lot of hard work, I managed to fix the hinge positions, installed the aileron servos, and positioned the upper stringers in preparation for the upper surface planking.

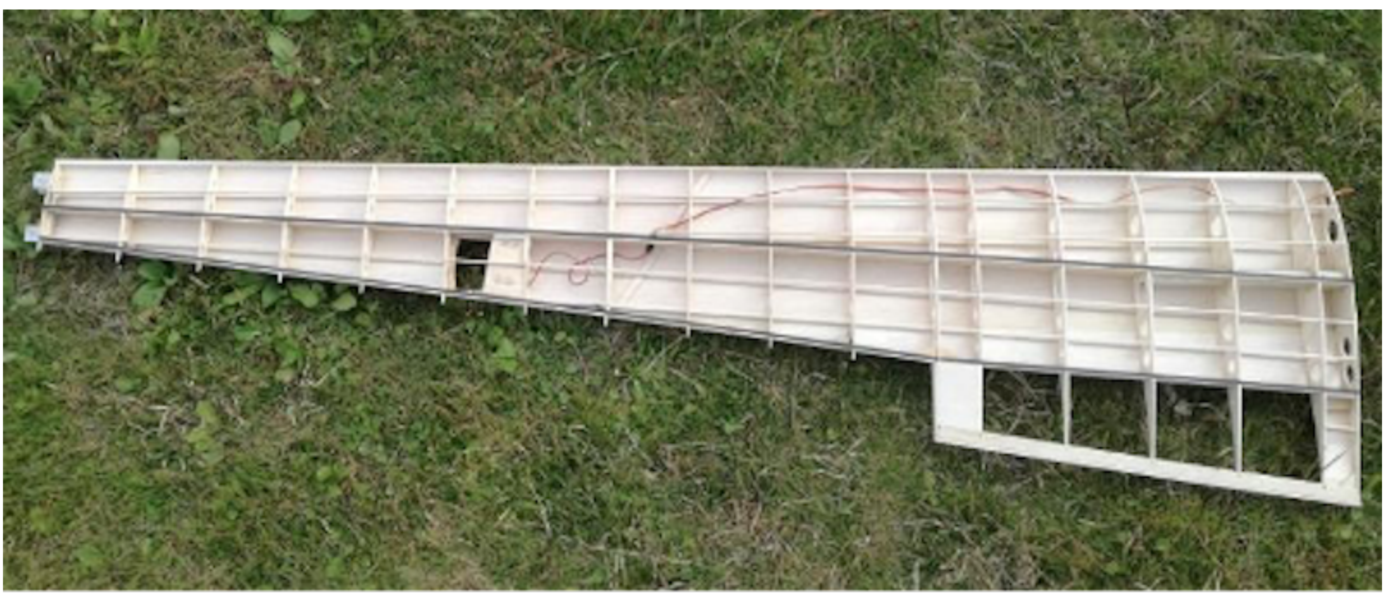


Photo 106: The outer wings with the lower plank completed.

Planking the Upper Surfaces of the Outer Wings

Next, I started to plank the upper surfaces. In order to apply the plank material within five minutes after the application of the titebond adhesive, I divided the plank sheet into two and attached them separately based on the experience with the center wing. For this purpose, a rib of the same shape was attached to the rib at the separation point to make a glue margine. The method of attaching the planks and holding them down on the assembly jig with thin cypress sticks and rubber straps is the same as for the center wing (see photo 94).

The work went smoothly up to this point, but when I connected the outer wings to the center wing, I found an unexpected problem. As the leading edge of the outer wing has a swept back angle of 0.57°, its effect appeared as the innermost rib of the outer wing was not parallel to the outermost rib of the center wing. There is about a 4 mm gap between the two wing's leading edges.

Photo 107: The connecting surfaces of the center wing and the outer wing do not meet!

This was not acceptable and I had to fix it, but since the outer wing has a dihedral angle, it was a little difficult to fill the gap. I attached two pieces of 2mm balsa sheets in a staircase shape on the innermost ribs of the outer wings and then, by connecting them to the center wing, fixed it carefully with a file while checking the condition. At the same time, the leading edge was shaped to complete the wing shape.

Photo 108: The revised connecting surfaces.

I'm sure if a person who is good at crafting did it, the gap would be invisible, but with my skill, I have to accept this level of completion.

Aileron and Wingtip Attachment

After attaching the lip that covers the top of the leading edge of the aileron, the aileron was attached and the length of the lip was adjusted to secure the aileron operating range. Then, I attached the wingtips and shaped them so that the outer wing contour and wingtip are smoothly connected.

Photo 109: Finished outer wings.

Main Wing Assembly

I connected the outer wings with the already completed center wing to make one main wing and put it on the fuselage with tail wings.

Photo 110: Main and tail wings assembled on the fuselage.

The shape of the aircraft is gradually becoming clearer and clearer, which makes me excited.

7th Calculation of Weight & balance

I recalculated the weight and balance because the skeleton of the wing and the fuselage were completed. The weight of the center wing is 1,715g at present. The remaining work is expected to be 190g for covering and 30g for painting. The outer wings weigh 818g on the left and 833g on the right. The remaining works are expected to be 155g for the left wing and 154g for the right wing, due to the counterweight, covering and painting. Based on these data, the revised weight and center of gravity calculation table is as follows.

7th Weight & Balance	2018/11/25	Completion Ratio		59.21 %			
	Predicted Weight	STA	Moment	Actual Weight	Estimated Remain Weight	Target Weight	Predicted-Target
Outer Wing Left	**973**	890	865,970	818	155	700	273
Outer Wing Right	**987**	890	878,430	833	154	700	287
Center Wing	**1,935**	890	1,722,150	1,715	220	1,720	215
Fuselage	**2,793**	869	2,427,117	1340	1453	1,600	1,193
Vertical Tail	**212**	2,450	519,400	172	40	240	-28
Horizontal Tail	**378**	2,270	858,060	266	70	400	-22
Motor	418	43	17,974	0		361	57
Propeller & Hub	50	-10	-500	0		50	0
Battery for Radio	155	200	31,000	0		155	0
LiPo	600	340	204,000	0		600	0
Others	186	250	46,500	0		634	-448
Total	**8,687**	**871**	7,570,101	**5,144**		**7,160**	1,527
Target CG		**846**					
Weight	322	160	51,522			0	322
Normal Flight Condition	**9,009**	846	7,621,623			**7,160**	1,849

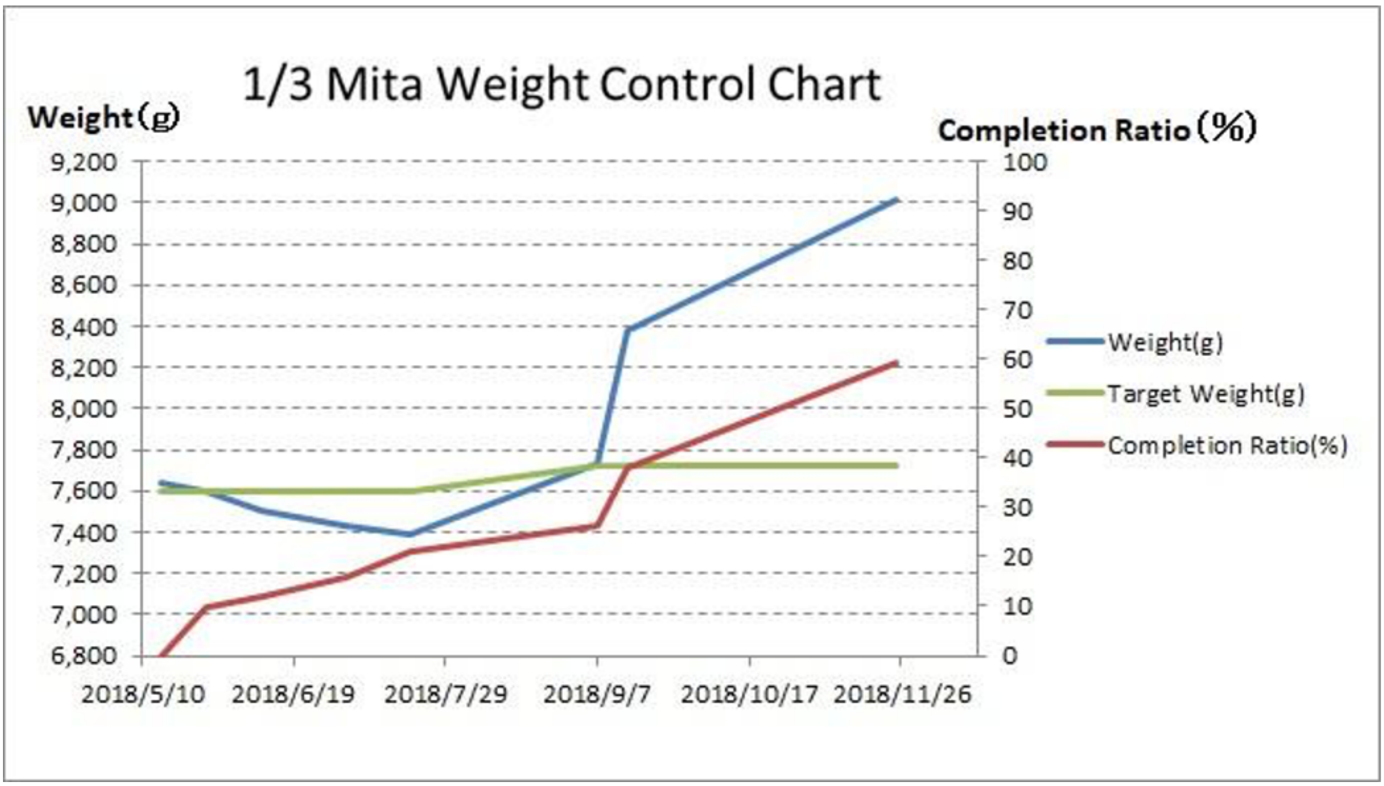


Table 8: The 7th calculation of weight and center of gravity.

The total weight is expected to be 8,687g, and together with the 322g weight required to balance, the total weight is expected to be 9,009g. As predicted earlier, the target weight for the wing and fuselage were too small. The completion ratio is 59.2% and there is not much room remaining for weight reduction in the future.

*This is the fifth part in this series. Read the **next article** in this issue, return to the **previous article** in this issue or go to the **table of contents**. A PDF version of this article, or the entire issue, is available **upon request**.*