MANUFACTURING TECHNOLOGY

WOODEN PROPELLERS AXIAL

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Yekaterinburg

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Axial wooden propeller manufacturing technology – Yekaterinburg. Ravill replica propeller, 2012. - 57 pages.

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Introduction

Unfortunately, very little attention has been paid to the history of wooden propeller production in Russian literature. To write this article, the author had to analyze extensive foreign literature on propellers dating back to World War I. A propeller is a complex component of aircraft design, not only for its calculation and design, but also for its manufacture. The high stresses to which propeller blades are subjected place special demands on their manufacture. Propeller manufacturing requires skilled carpentry, knowledge of the proper tools, and the ability to use them. Here, we will examine in detail the manufacture of the Axial wooden propeller for the Fokker DR1.

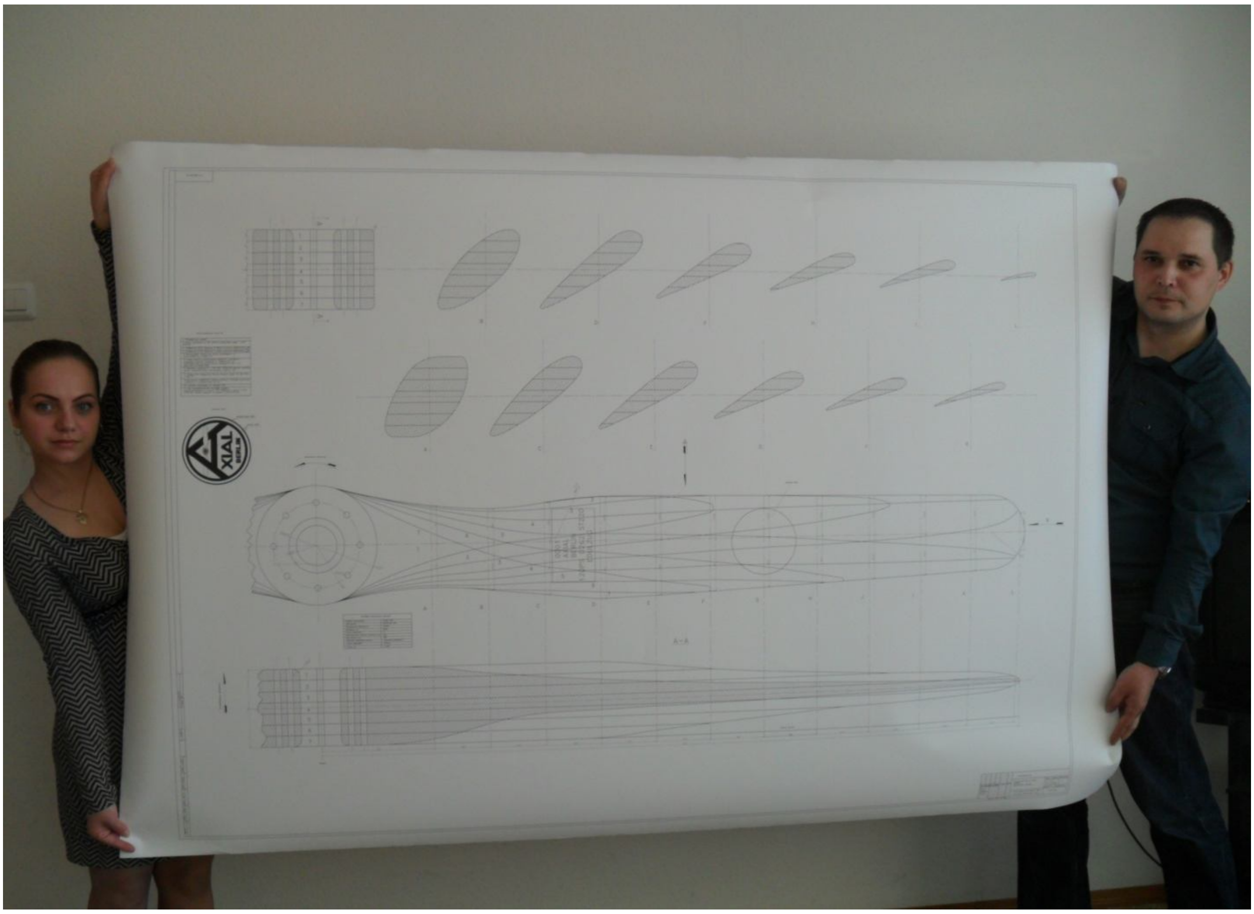
Beginning in 1916, Axial propellers were arguably the most common type on German aircraft until the end of World War I. This was due not only to their superior technical characteristics but also to their relative ease of manufacture compared to other propeller types, making them quick and inexpensive to produce, which was crucial during wartime.

After the end of World War I, the Allies demanded the cessation of propeller production. Axial Propellerwerke, like many other propeller manufacturers, was closed, and all of the factory's products were destroyed. Fortunately, many well-preserved examples of these propeller types have survived to this day and are now housed in museums and private collections. Today, enthusiasts of the early aviation era, restoring their production technology, use them to create replicas for airplane replicas.

Author: Islamov R. A.

Main technical data of the Axial propeller for the Fokker DR1

Screw type	pulling, unchangeable, variable pitch
(the sections have different geometric pitch)	
Work scheme	straight
Direction of rotation	right
Screw diameter, m	2,620
Step	2200 mm
Hub thickness	140 mm
Hub diameter	210 mm
Number of blades	two
Material	walnut \ birch



Brief description

The propeller is a single piece, glued together from gorse and machined so that the blades extend from the hub. The blades are of variable thickness, gradually thickening toward the root. The propeller profile has a convex working section near the hub. The sections near the root are not profiled.

The Axial propeller is made from walnut and birch. Each propeller consists of seven brooms (the brooms are 20 mm thick).

The hub has a through hole and is clamped with eight bolts into a steel bushing. The bushing consists of a flange with a protruding cylindrical section that fits into the propeller hub hole and onto the splines of which a second (removable front) flange is mounted.

Use of tools and equipment

Humitest MC 300WS Electric Moisture Meter

Pencil simple constructor TM

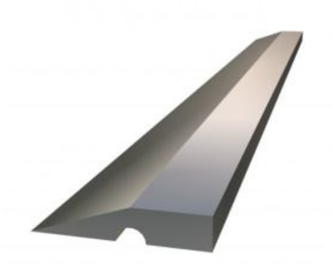
Solid metal square or adjustable square with FIT level

Stabila level 100 cm

Lux-tools 60mm and 20mm natural bristle flat brush

Construction rule 3m Sibirtech



Enkor manual rotary vice

Carpentry workbench VSt-M

Bosch Gof 2000 hand-held router

Bosch groove cutter D 8 mm

Bosch groove cutter D 3 mm

Bosh R12mm ball bearing rounding bit

Vertical drilling machine 2n125

Jigsaw Black Decker KS1000E

Thicknesser Makita 2012NB

Hitachi SV-12V orbital sander

Bosch PWS-115 Angle Grinder

Hitachi SB8V2 Belt Sander

PFERD files: semicircular, round, flat No. 1, 2, 3 L 100-250 mm

Vira needle file set

Narex chisel set

Mirka sanding paper with grit up to P2000

Wooden plane (sanding block) 190x55 FIT

Stanly rasps, L 250-300mm, flat, semi-circular, round

Hand-stamped stamps, Latin font, digital Pryor

Twist drill bit for wood 10x230 Enkor

Stayler Adjustable Wood Drill Bit 22-76

Pfeil straight planer PF-ZUGSD cutting part 250 mm

Clamp, forged 120 x 200 – 10 pcs. type F Enkor

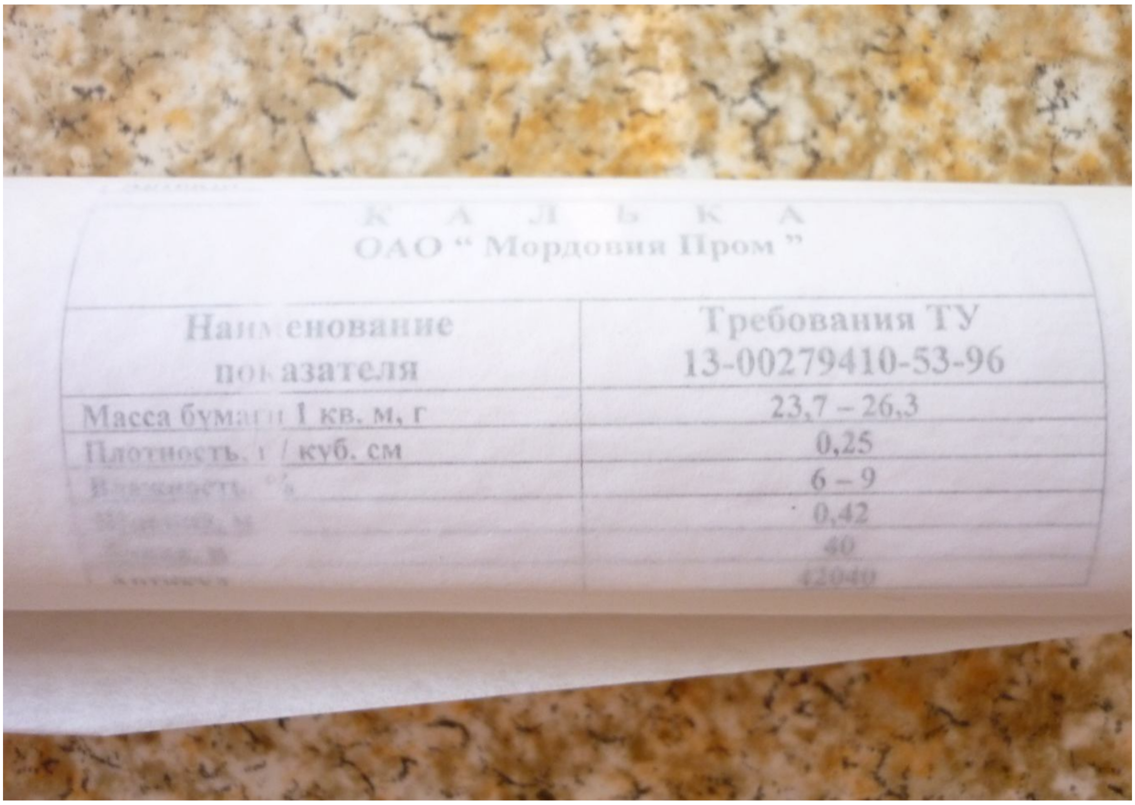
Clamp, forged 76 x 150 – 10 pcs. type G Enkor

Stayler 60mm Rubber Spatula

Making gorse templates

Before you start making the propeller, you need to make seven propeller gorse templates.

To make broom templates, you need to prepare tracing paper, 8mm plywood, wallpaper glue, such as Kelid Express, and a flat brush.



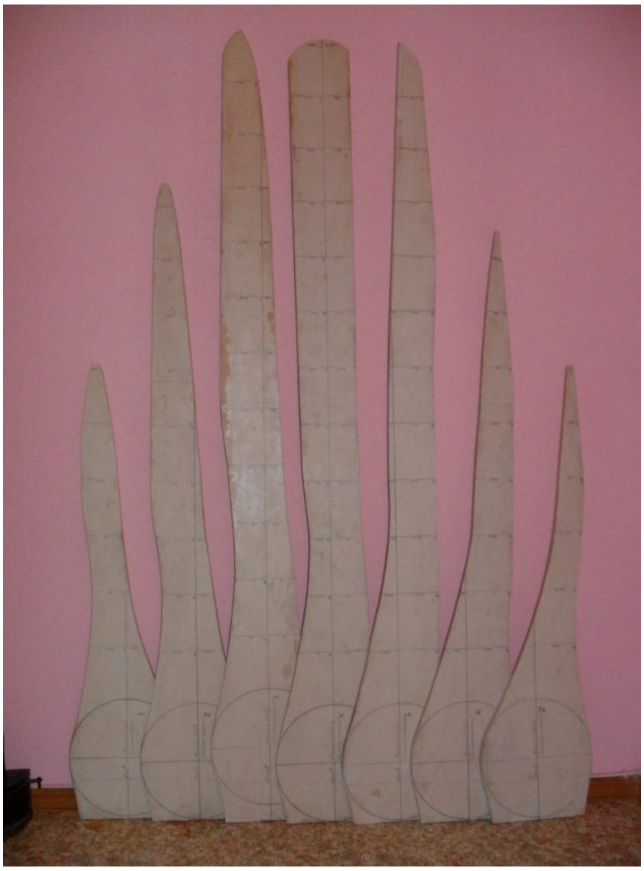
We cut out template blanks.

We transfer the contours of the gorse, center lines and section lines of the profiles onto tracing paper.

Apply glue using a 60 mm flat brush to the surface of the template blank and glue the tracing paper.

This may not work the first time – tracing paper tears easily, so the movements must be smooth.

Once the glue has dried, you can start cutting out the templates.

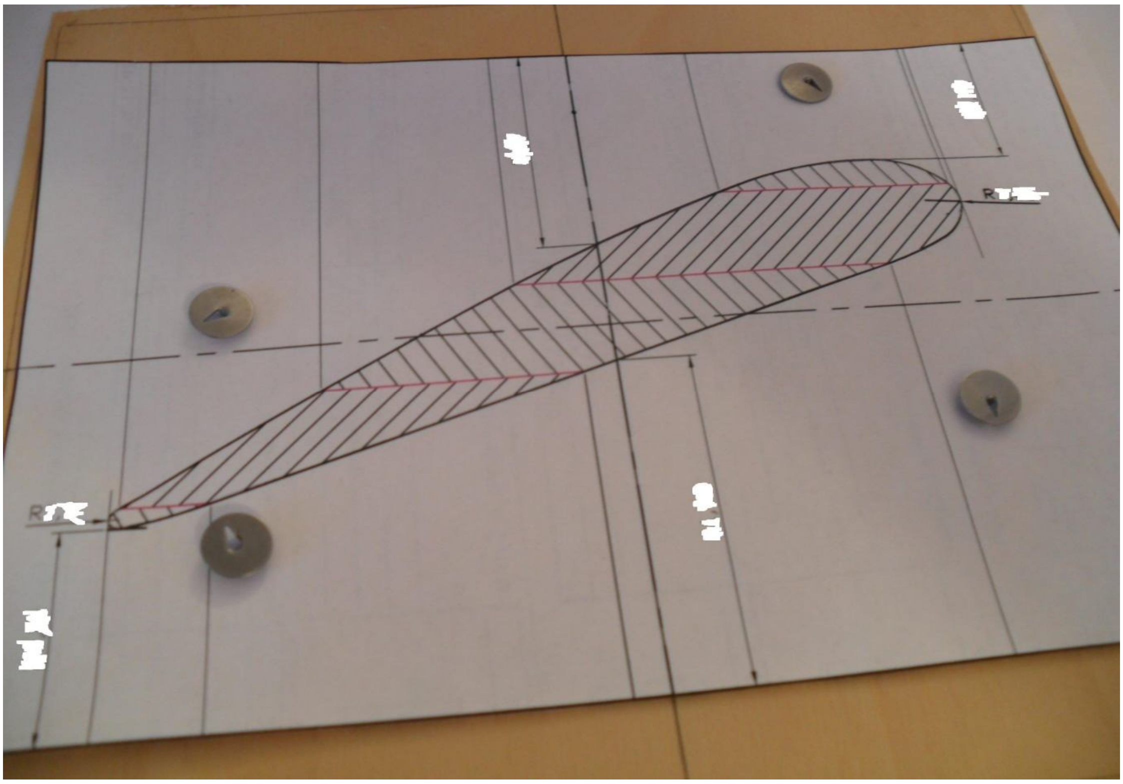


Production of control section templates

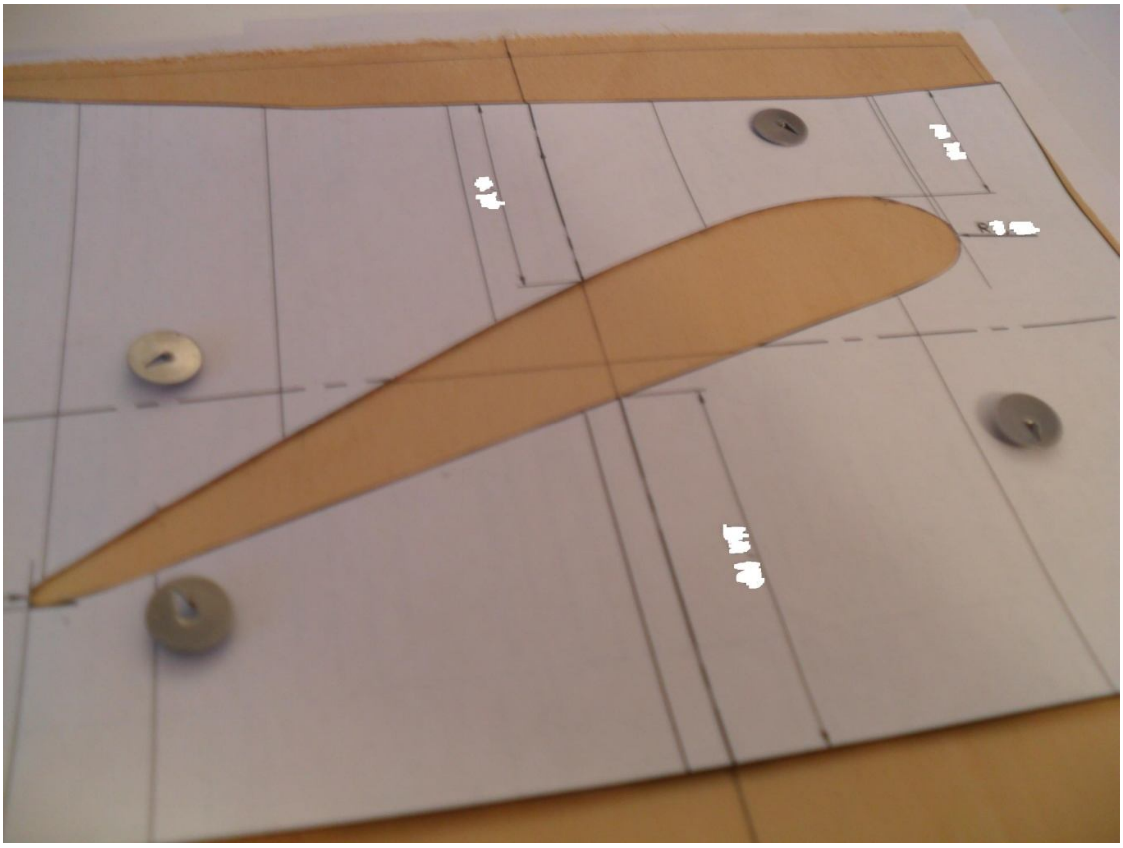
Control sections are spaced every 100 mm starting from a radius of 200 mm – a total of 12 sections. Each section is assigned a letter of the Latin alphabet (A...L). Therefore, it is necessary to make 12 control section templates for the working section of the propeller and 12 control section templates for the upper end section of the propeller according to the drawing.

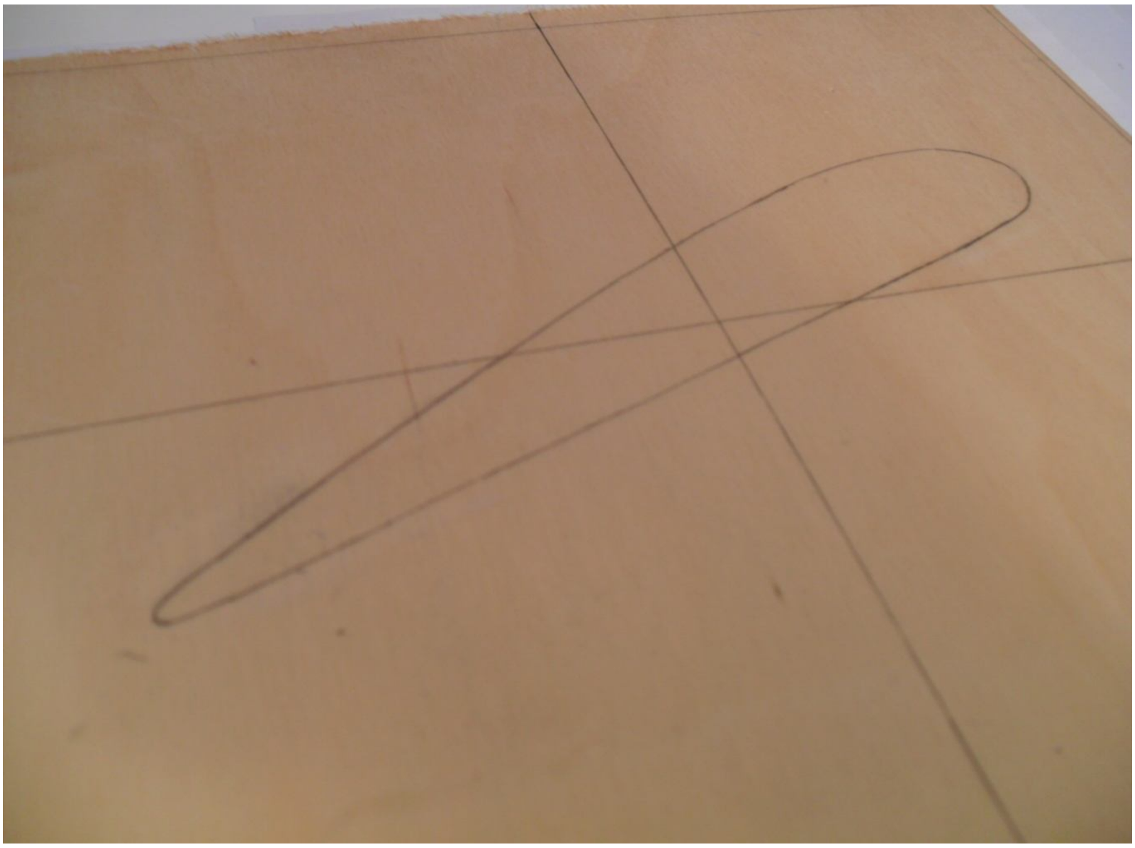
First, you need to cut out blanks from three-layer plywood measuring 160 x 230 mm, i.e. 10 mm on each side larger than the diameter and thickness of the hub.

In the center of the template blank, select the "0" point and draw the centerlines through it. Attach the printed section of the control profile to the blank with thumbtacks, aligning the centerlines.

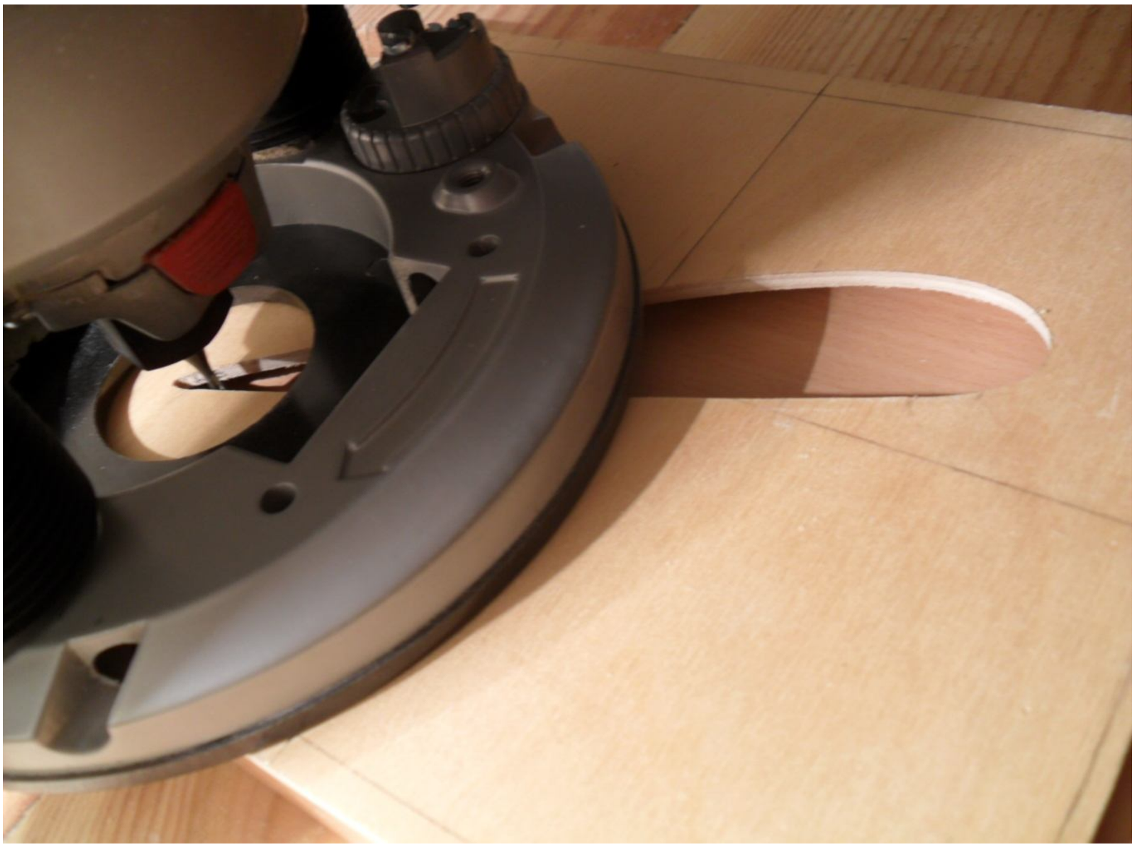


We cut out the outline from the inside and trace it with a pencil.





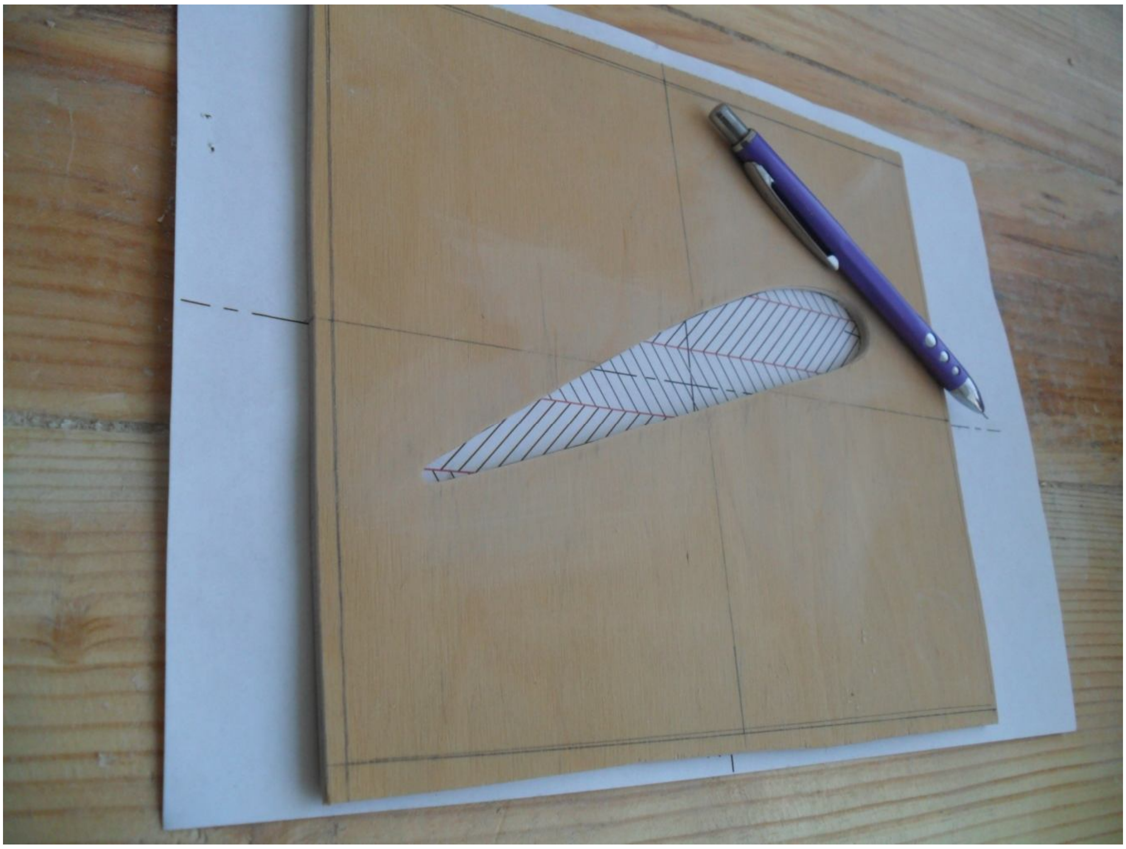
Next, we use a router to cut out the outline from the inside.



Use Bosch D 8, D3mm groove cutters and a special lining that creates free space for convenient, unobstructed milling.

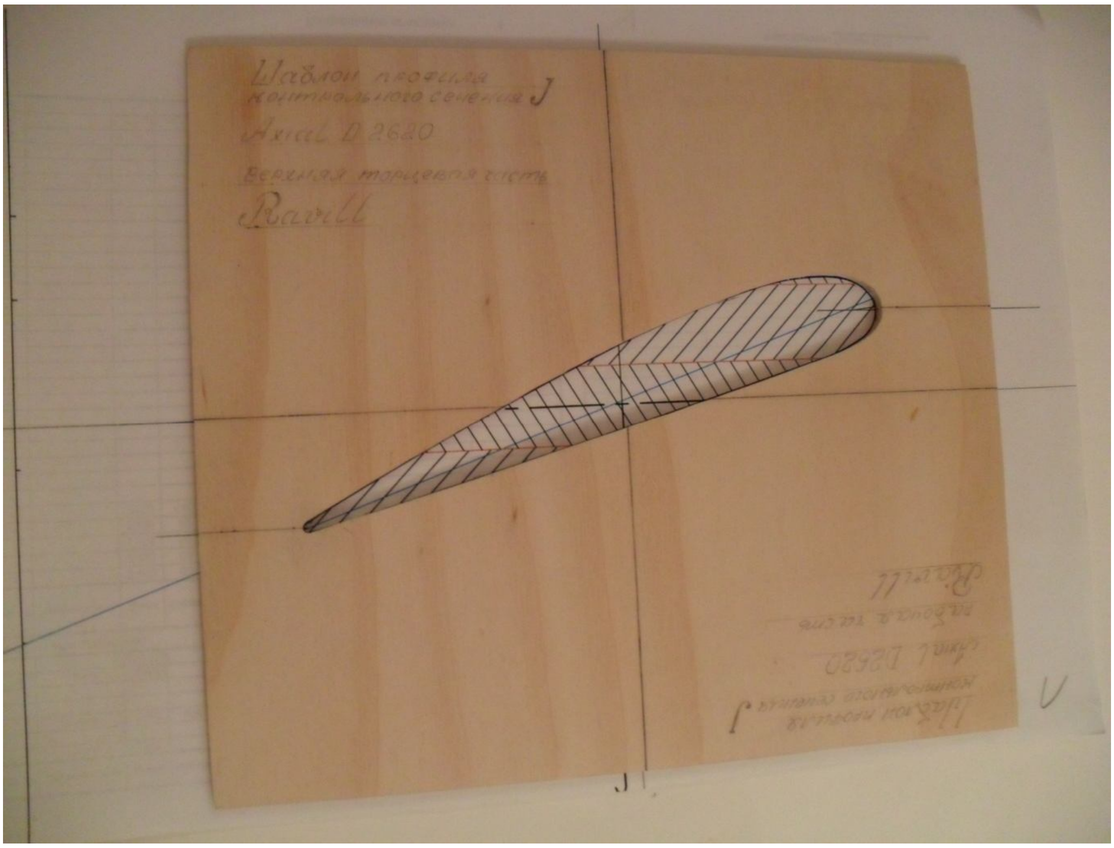
Using files and needle files, we finish the outline until it matches the drawing.

It is necessary to strive for high precision in their manufacture.

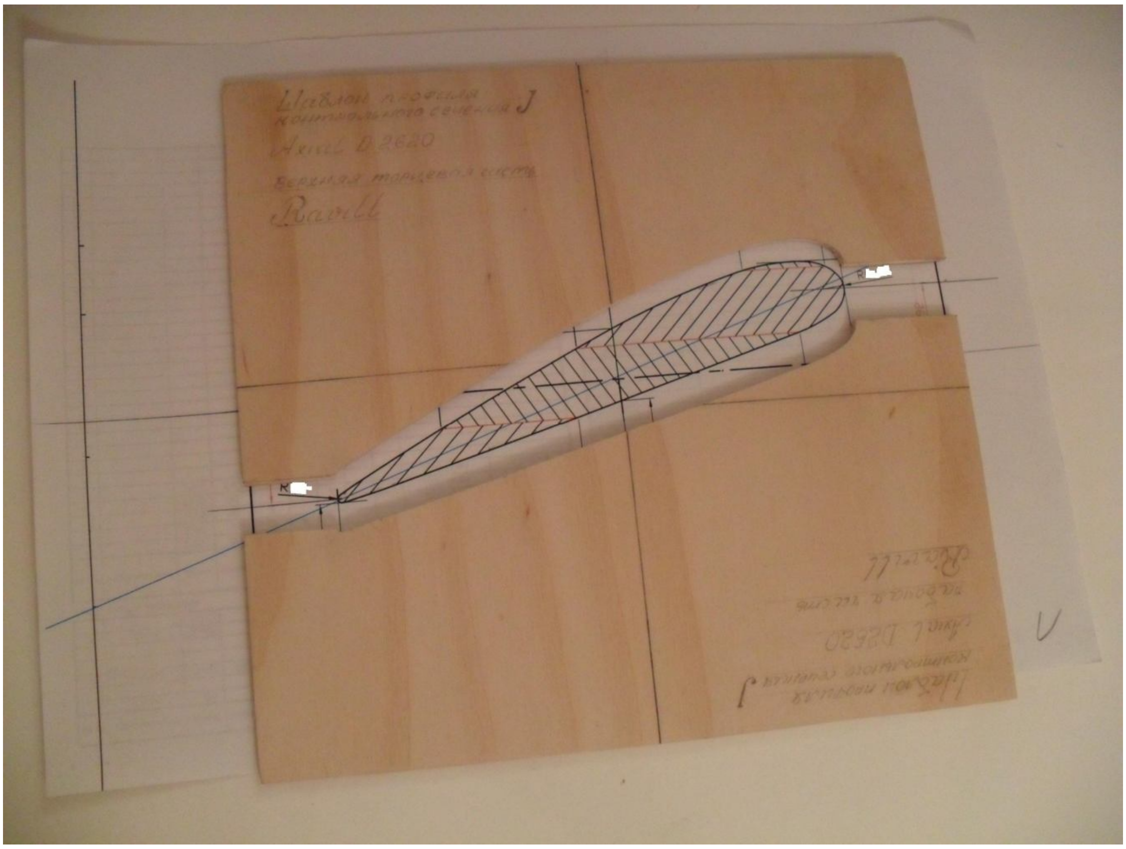


We constantly check the profile against the drawing.

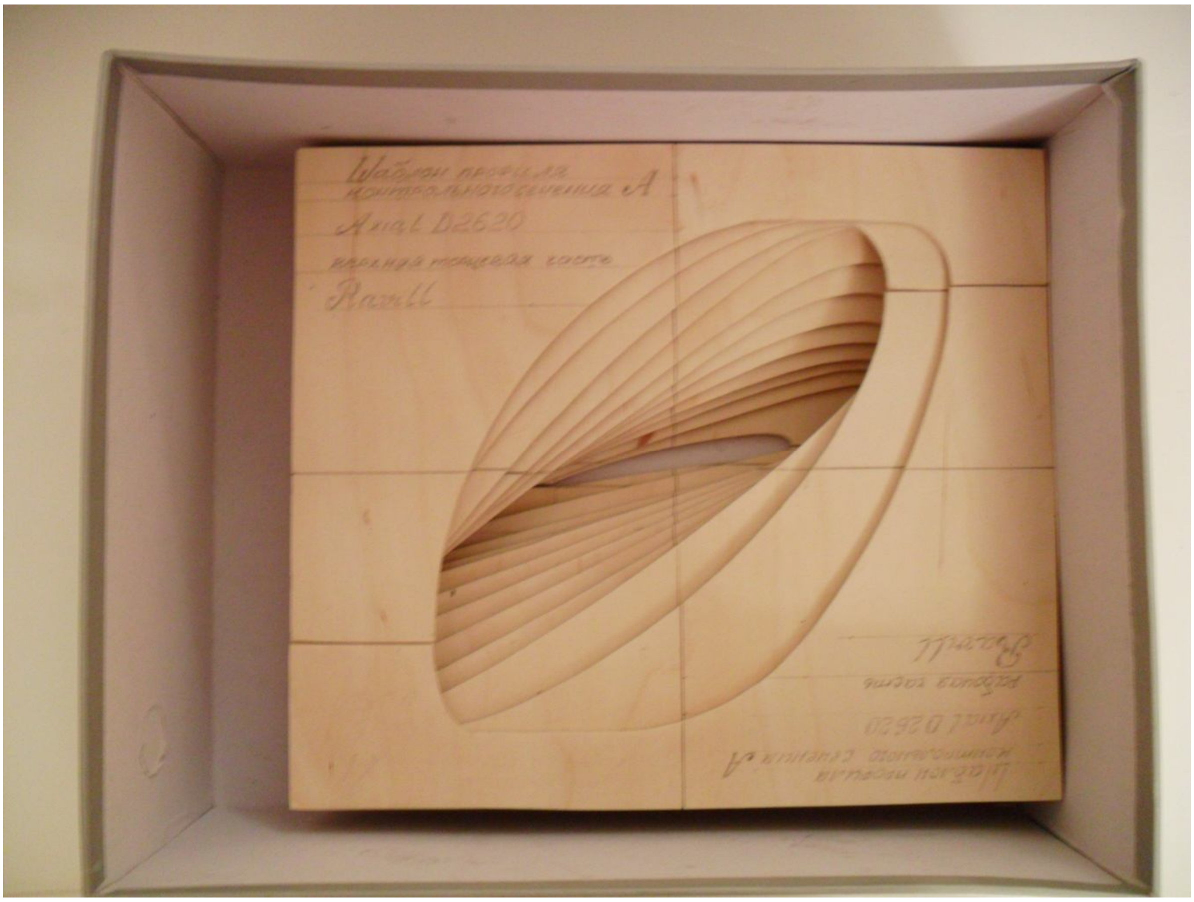
Sand the surface of the template blank.



We sign each part of the profile and mark the dividing lines between the parts.



We divide the workpiece into two parts.



We repeat this process with all the templates and place them in the prepared box. Done!

Historically accurate wood type

Axial used walnut and birch for most of its propellers. Birch wood has a uniform density, with barely visible growth rings. It is highly resistant to splitting, making it particularly suitable for propellers. Walnut is the best material for propellers. Propellers made with walnut can operate at very high peripheral speeds, where other woods would be unsuitable. Gluing together blanks of different woods increases their strength, as it eliminates the possibility of weak points in the wood's structure overlapping; it also prevents warping due to shrinkage. This combination may also be due to the fact that walnut is one of the stiffest types of wood, while birch is more flexible. Thus, the birch gorse acts as an elastic bond between the stiffer walnut gorse. In addition, the strong color difference between walnut and birch makes finishing the screw much easier.

There are also reports of propellers made by Axial, which were crafted from the gorse of three different types of wood, with varying amounts of gorse and thickness. Keep in mind that propeller gorse thickness can vary from 10 to 30 mm.

Selection of material

The next step is choosing the material. When selecting boards, pay attention to the arrangement of the growth rings within the wood (this is clearly visible on the end grain), giving preference to boards with horizontal or inclined grain, cut from the part of the trunk closest to the bark. Use only wood that has grown straight. Visible wood defects (knots, cracks, etc.) should be inspected in accordance with GOST 2140-81.

A board is rarely perfectly flat. Sometimes its thickness may vary slightly along its length or it may warp slightly during the drying process. Therefore, it is recommended to purchase boards 25 mm thick and, after sawing, plan the gorse to the required size of 20 mm, and the upper first and lower seventh 22-23 mm (allowing for finishing allowance), eliminating any unevenness.

Cutting gorse can only begin after the boards have dried to a moisture content of no more than 12-15%. The reason for this is simple: problems can arise when gluing the gorse, as the wood cells are filled with moisture. Another problem is that gorse from freshly cut boards can shrink significantly in size shortly after gluing.

To prevent cracking of the blanks during drying, their ends should be painted with oil paint or drying oil. This process is often performed at sawmills.

Drying wood

There are two types of drying of lumber: chamber and atmospheric.

Kiln drying is the primary method of drying lumber in drying chambers equipped with the necessary equipment and instruments. The chambers are equipped with regulated temperature, humidity, and air circulation. Kiln-dried wood should have a moisture content of no more than 13%.

Atmospheric drying is natural drying in the open air under a canopy.

The ideal wood for propellers is air-dried wood for 5 to 7 years. The technical qualities of this wood (in terms of brittleness and warping) are significantly higher than wood dried immediately after sawing, but it can be difficult to find commercially.

Determination of wood moisture content

The following methods for determining humidity are used in practice:

Weight

This method is used in large enterprises with their own drying ovens. Using the weighing method, a section of 10-12 mm thick moisture content is cut from a board (control sample) at a distance of 300-500 mm from the end face, carefully cleaned of burrs and sawdust, and weighed. The result is recorded in a log, and the section is placed in a drying oven with a temperature of up to 103°C. After 6 hours of drying, the section is weighed and the weight recorded in the log, then dried again and weighed every 2 hours after drying. If the section's weight remains unchanged after repeated weighings, this means the section has dried to a completely dry state with a moisture content of W0 = 0% and a mass of P.

The initial moisture content of the wood sample is determined by the formula:

$$W = (P_н - P_c) : P_c * 100\%,$$

where W is the initial moisture content, %;

$P_н$ and P_c are the initial mass and the mass in an absolutely dry state of the sample.

Method of weighing control samples

Current moisture content can also be checked during the drying process by weighing control samples at least 1000 mm long. These samples are also cut from the boards to be dried, 300-500 mm from the end face, cleaned of bark, burrs, and sawdust, and then painted. The samples are weighed to an accuracy of 5 g.

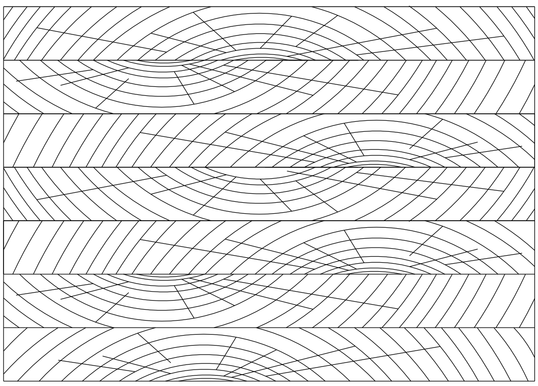
Electric

Electric moisture meters, which measure moisture in the range of 7-60%, are widely used today. This allows any buyer to monitor the moisture content of wood. They are used to monitor wood moisture at a distance of at least 0.5 m from the ends, at least three points along the length, and randomly.

Do not glue together brooms whose moisture content differs by more than 2%. Below is a demonstration of checking the moisture content of a walnut board using an electric moisture meter.

Sawing and preparing gorse for gluing

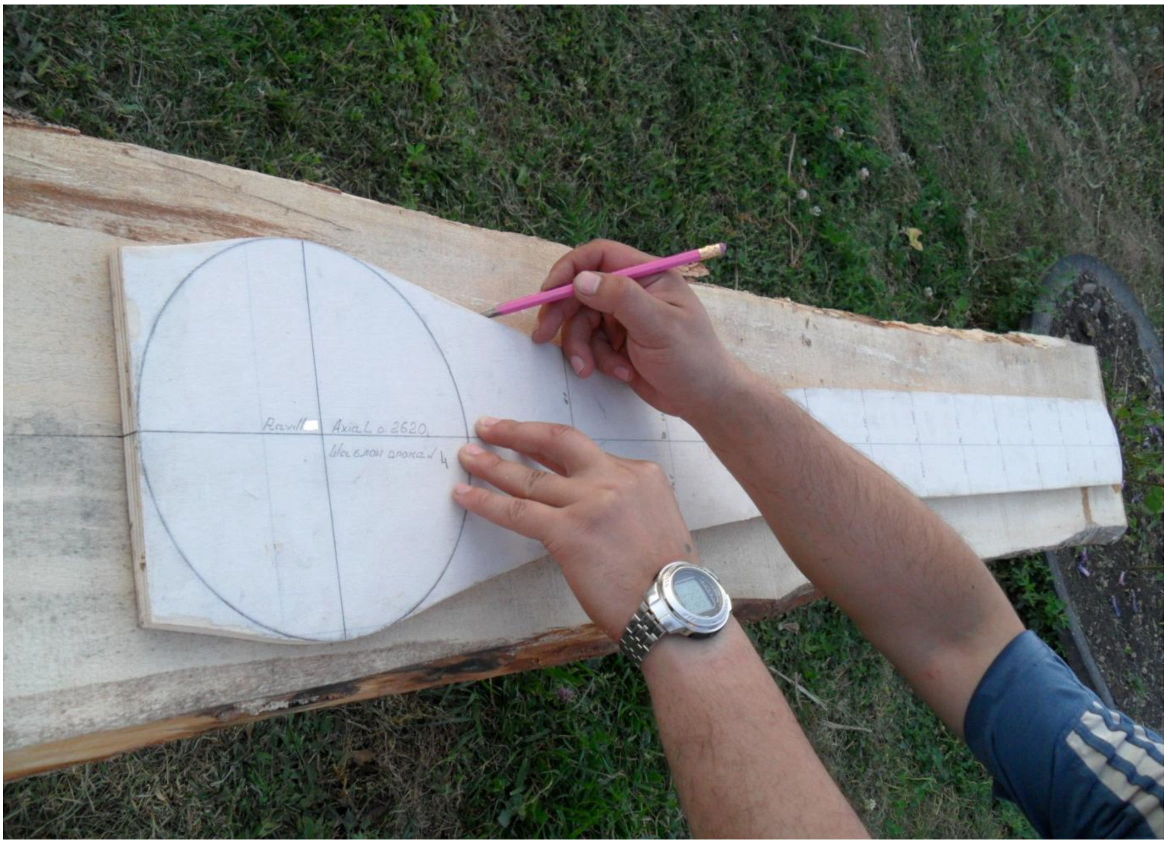
Before cutting broom, it's important to follow the rules for selecting it based on its annual rings. Incorrectly selected broom can swell unevenly, shrink, and warp, which will inevitably cause the propeller to warp relative to the blade's axis of symmetry. Such blade warping, in addition to altering its aerodynamics, causes propeller wobble, which is unacceptable during operation. The annual rings of adjacent broom should face different directions or be at an angle to each other, so that adjacent boards tend to warp in opposite directions.



The arrangement of the arches in the screw blank package.

The topmost and bottommost broom are always made from a harder type of wood (in our case, walnut) to minimize the hub's deflection from the bushing when tightening the bolts.

Using a building straightedge, we mark the center line on each board.



Having placed the blade template on the workpiece, aligning the center lines and temporarily securing it with nails, trace the outline of the template with a pencil.

Then turn the template exactly 180° and trace the second blade.

After this, you begin to cut out the drawn gorse from the boards.


LASER

When cutting the gorse, it's important to leave a 5-7 mm allowance on each side, as you'll need to painstakingly shape the propeller profile later. I recommend leaving a larger allowance for the length—you'll see how much easier it will be to work with.

After cutting the gorse, to obtain the required thickness and a smooth surface over the entire area, they must be run through a thicknessing machine.

Gluing gorse

The essence of gluing is that the adhesive penetrates the intercellular and intracellular spaces of the wood, hardens there, and thus stitches the surfaces together with a huge number of extremely fine threads. A very thin adhesive film forms between the surfaces being glued. The gluing process follows a specific sequence and includes the following steps: preparation of the surfaces to be glued; adhesive application; a holding period after the parts are placed before pressing; pressing; holding under pressure; and a holding period after gluing.

The gluing process is defined as a set of conditions that must be observed during all operations. The main conditions determining the gluing process are: room temperature and humidity; moisture content and condition of the wood surfaces being glued; the amount of adhesive applied per unit of surface area being glued; gluing pressure and duration of holding pressure; gluing temperature; and post-gluing holding time.

Gorse should be glued soon after planing. After prolonged storage of wood prepared for gluing, it often needs to be planed again, as the surface pores become clogged with dust, and warping may also occur.

To increase the strength of the bond, the surfaces of the broom to be joined must be roughened using coarse (P40) sandpaper, either manually or with a grinding machine - this improves adhesion during gluing.

Gluing should be done on a workbench, table, or special stand of appropriate height. The work area should be well-lit. The gluing area should be kept dust-free. Dust settles in the wood pores and impedes adhesive penetration. This will result in poor gluing quality.

The woodworker/gluer must work in clean clothes and with clean hands. Cleaning materials must be available at the workstation to remove any squeezed-out glue from the workpiece.

Before gluing the gorse, make sure that there is no dust, grease stains or any other materials that reduce adhesion on their surfaces.

A constant air temperature of 20— should be maintained in the gluing room. 30. No natural or artificial drafts are allowed in the room. Even the slightest draft will cause a thin, gelatinous film to form on the surface of the adhesive applied to the wood, preventing a strong bond. Therefore, the room should be isolated from other areas by tightly closing the doors.

To apply the adhesive, use a rubber or plastic spatula with fine teeth to ensure a more uniform layer. Apply the adhesive evenly to both surfaces, using quick strokes. Applying the adhesive to one side does not ensure uniform wetting of both surfaces, resulting in uneven stresses in the glued wood, which reduces the bond strength. The amount of adhesive applied (or adhesive consumption) per unit of bonding area should be optimal and depends on the type of materials being bonded, the type of adhesive, the application method, and other factors. Applying too much adhesive excessively wets the wood along the joint, unnecessarily increases adhesive consumption, and wastes time and effort removing excess adhesive during pressing. In each

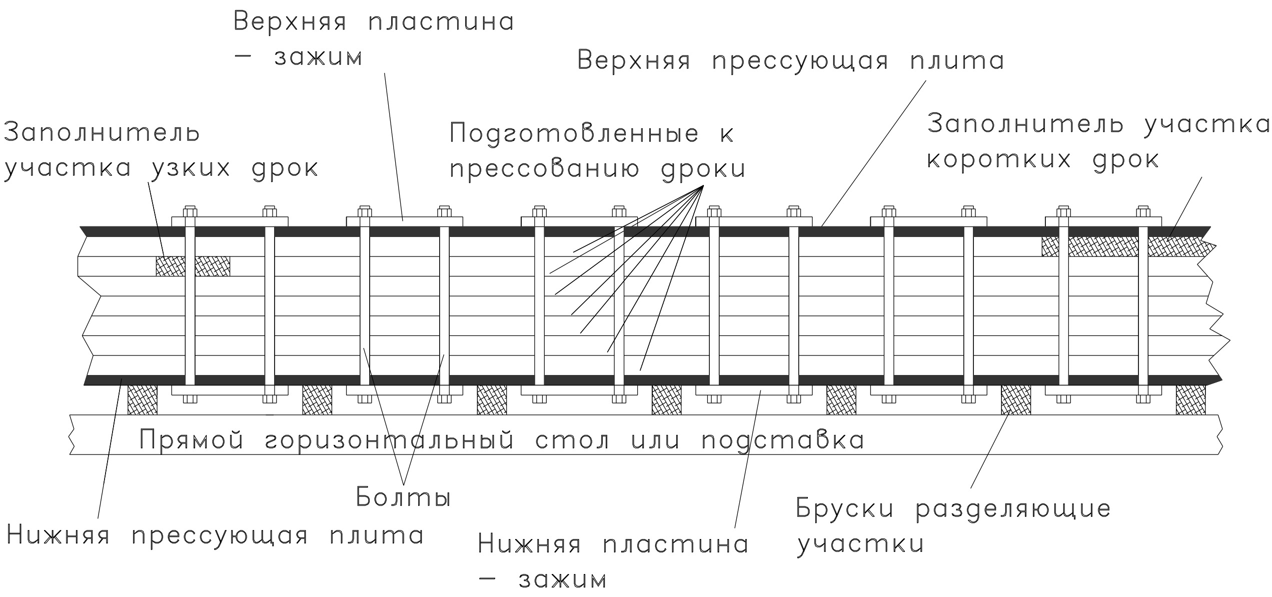
In a specific case, adhesive consumption standards are defined, the violation of which leads to a decrease in the strength of adhesive joints.

Before pressing (compressing) the piece being glued, it must be soaked for a period of time with the adhesive applied. A distinction is made between open and closed soaking periods. Open soaking is the period between applying the adhesive to the surfaces to be glued and joining them without pressure. Closed soaking is the period between joining the surfaces coated with the adhesive solution without pressure and pressing them together. During the open soaking period, not only does the wood become saturated with the adhesive solution applied to its surface, but moisture from the solution also evaporates rapidly. This reduces the wood's moisture absorption and simultaneously increases the concentration of the adhesive solution, allowing for higher pressure and, consequently, better adhesive penetration. The open soaking period is specified in the adhesive's specifications and should never be exceeded.

Closed curing promotes better impregnation of the wood with glue and delays the onset of its gelling.

The set of gorse, with the center lines aligned, is tightly pulled together with at least 20 clamps, starting from the hub and gradually moving towards the ends, and held under pressure until the glue has completely set.

Previously, special clamps were also used for gluing, which allowed for a more even distribution of pressure over the surface of the workpiece - see below.



Pressing should be done as close to the adhesive's curing time as possible, but never during or after curing. Pressing pressure is also specified in the adhesive's specifications and depends on its type. The higher the concentration and viscosity of the adhesive solution, the greater the pressure required for pressing.

When pressing, care must be taken to ensure that the workpiece does not bulge or become distorted.

The glued parts are held until the adhesive has fully set, i.e., until the moment when neither disintegration nor displacement of the bonded parts is possible and the risk of weakening the glue joint is eliminated. The duration of the holding pressure, or pressing time, depends on the curing time of the adhesive, the moisture content of the wood, the pressing temperature, and the type of wood being glued. When gluing hardwoods, which absorb water more slowly, the holding time is longer than when gluing softwoods. Gluing all the gorse in one step requires a longer holding time than when gluing individual pieces separately, as a large amount of moisture is introduced with the glue.

The greatest strength of glued structures is achieved with an adhesive seam thickness of about 0.08–0.15 mm; with its large thickness, the bonding strength decreases. Thick
Due to the adhesive's high hygroscopicity, the adhesive interlayer can even cause the adhesive to delaminate due to changes in temperature and humidity. Furthermore, a thick interlayer will shrink significantly during drying, leading to cracks. This also reduces the bond strength. A very thin adhesive interlayer (less than 0.08 mm) is also unacceptable. Such an interlayer will lose its continuity, resulting in only a partial, very weak bond.

In bonded parts released from the press, the adhesive joints may be damaged and weakened during subsequent processing if performed shortly after unpressing. Furthermore, during gluing, the parts absorb moisture from the adhesive solution. Therefore, it is necessary to allow the moisture to equilibrate for up to two days after unpressing.

In general, initially, gluing of propeller shafts was done with gelatin glues, sometimes also casein, but now there are many other glues with higher performance characteristics.

I recommend:

"Ponal Super 3"

A one-component, waterproof, white wood adhesive based on polyvinyl acetate. High bond strength meets DIN EN requirements.

204, class D3 resistant to aging

Glue characteristics

pH value: approx. 3

Heat resistance according to WATT 91> 7 N/mm².

Density approx. 1.1 g/cm

Application temperature: not lower than +5 °C, both ambient and material temperature.

Consumption: approx. 150 g/m2 depending on the absorbency of the surface.

Open time: max 12 minutes at room temperature (+20°C).

Pressure force depending on the structure, shape and thickness of the material.

Pressing force for gluing hardwood 0.3 - 0.7 N/mm2

Titebond II Transparent Premium Wood Glue

Titebond II Transparent Premium Wood Glue is the only one-component adhesive that meets the stringent ANSY Type II standard for moisture resistance. After drying, the adhesive becomes clear, provides a strong initial tack, and short press times.

Glue characteristics

Titebond II Transparent Premium Wood Glue is a PVA-dispersed wood adhesive that provides a bond strength superior to the wood itself. Non-abrasive: it won't damage cutting tools during finishing. It also has excellent resistance to heat and solvents.

Color: colorless;

Properties: moisture resistant;

Drying time: 24 hours;

Apply at +12°C, operating temperature range: -30 to +50°C. Consumption is 180 g per m². Working time: 10-20 minutes, depending on conditions.

Pressing pressure for soft wood is 7 kg/cm², for medium wood 10 kg/cm², for hard wood 15 kg/cm².

Titebond glue meets the requirements of ASTM C557 (USA) and AFG-01 D3498 of the American Plywood Association, DIN EN204 D3.

"Bindan-P Propeller Leim"

Bindan-P is a waterproof, transparent wood glue based on environmentally friendly, high-quality synthetic resin. It is filler-free, solvent-free, and formaldehyde-free. Bindan P B3/D3 adhesive complies with DIN 68 602/EN 204.

Glue characteristics

Heat resistance according to WATT 91> 7 N/mm².

The average breaking load is 1400 kg/cm².

Minimum operating temperature + 10 ° C.

Favorable humidity: 8 - 12%.

Open time of application at T about 20 ° C: 8 - 10 min.

Pressing temperature from + 15 ° C to + 80 ° C.

Pressing pressure about 0.7 N/mm², at temperature (20 +/-2) °C.

Personally, I'm categorically against using epoxy glue. You'll get burned out with it right at the manufacturing stage. Furthermore, using it to machine the workpiece will ruin the entire tool. In fact, I'm sure a screw made with it will fall apart very quickly during use, as it bends slightly as it rotates, and epoxy glue, due to its monolithic nature, doesn't tolerate bending and begins to crack. Furthermore, it's highly toxic in liquid form.

I know that many replica airplane builders widely use two-component resorcinol adhesive for gluing propeller shafts and wooden wing components (rib flanges, spars, etc.). It's also widely used in yacht building. It's dark brown, completely waterproof, has high chemical and mechanical resistance, and can withstand wide temperature fluctuations. The downside is that it contains phenol formaldehyde, which is highly toxic.

Tools used to make screws during World War I

Drilling holes

When choosing a drilling machine, consider the spindle stroke to ensure holes are drilled in one pass. The machine's spindle stroke should be at least 150 mm. For example, the 2N125 vertical drilling machine has a spindle stroke of 200 mm.

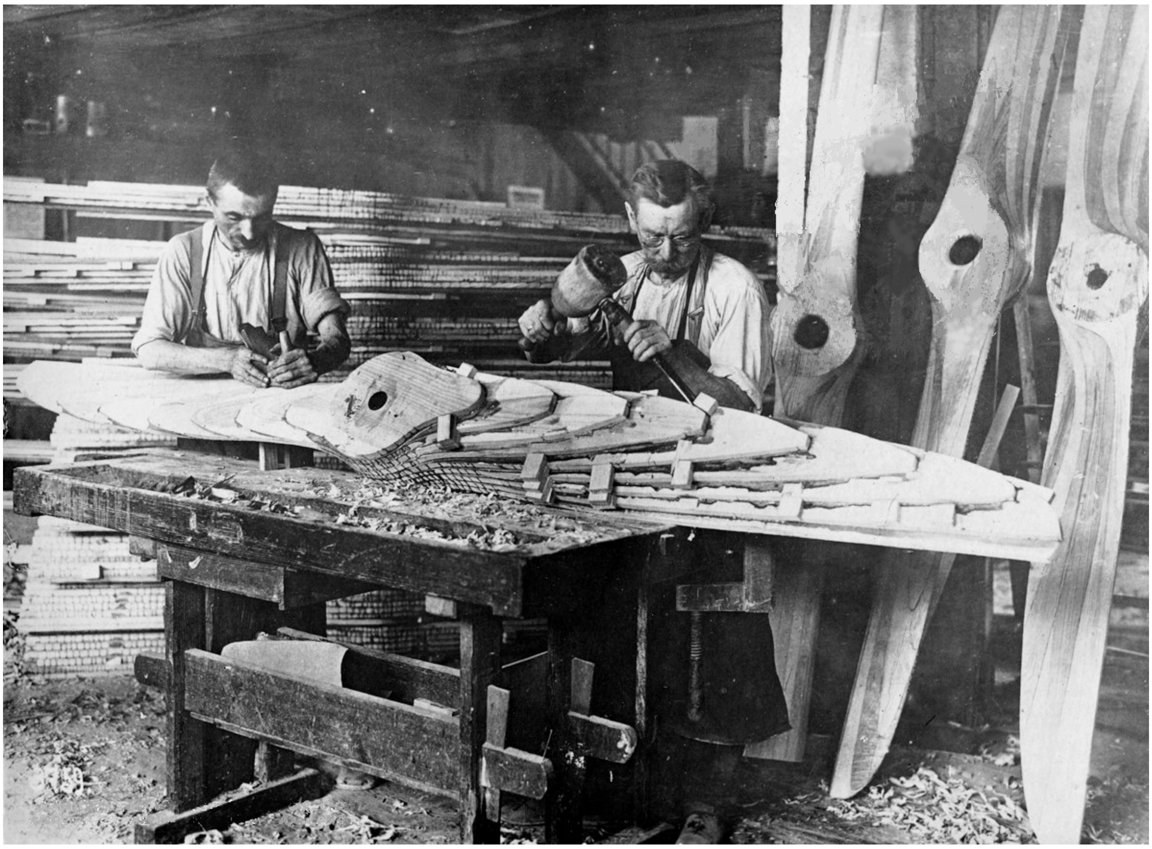
According to the drawing, mark the holes for the bolts and bushing on the hub surface. Using a drilling machine, drill the holes for the bushing and the bolts strictly perpendicular to the plane of the screw. Use a special drilling jig. Drill the bolt holes at a minimum spindle speed of 2000 rpm. Use a twist drill—it's best for drilling deep holes.

When drilling the bushing hole with a Stayler adjustable spade bit, use low speed and low feed. Wear safety glasses when operating the drill press.

After drilling the hole for the bushing, mill a radial internal chamfer.

Blade processing

The product has taken on the shape of a propeller. Now comes the most critical part of the work—shaping the blades into the desired aerodynamic profile. It's worth noting that previously, blade machining for propellers of this diameter was performed by two craftsmen, each responsible for the quality of their own blade. Generally, the entire machining process can be divided into two parts: rough and fine.



When rough-cutting, use a plane and a flat chisel to remove wood from the corners of the broom, shaping the profile gradually and slowly, first making small, short cuts to prevent chipping. Before work, check the condition of the chisel's cutting edge and the plane's blade (quality of sharpening, sharpening angle, absence of chips and dents). Once the chisel is properly sharpened, a mallet is practically unnecessary—the chisel should penetrate the wood without much effort. It's worth noting that walnut is much more pliable than birch, making it a pleasure to work with.

For each of the control sections, cuts are made in strict accordance with the section templates (with a margin of 3-4 mm).

The remaining space is processed later.

Wood close to the root can also be removed with an angle grinder,

and then to the ends using a belt or vibration sander.

Templates are not used for rough processing.

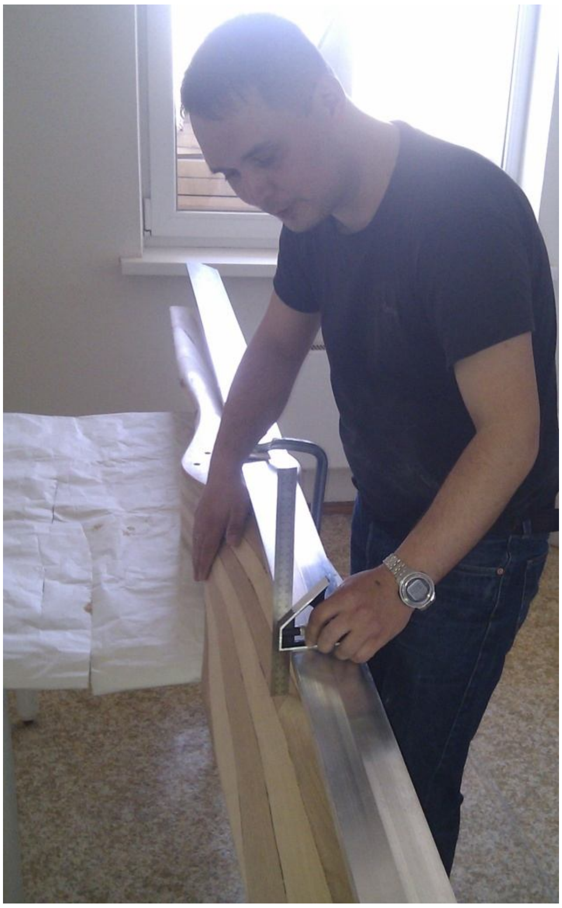
Afterwards, the control sections are marked again, and the location of the center line is marked on each section.

To mark the location of the center line, we apply a ruler to the surface of the hub.

Using a steel square, align the side plane of the straightedge with the centerline marks on the tips of both blades. Secure the straightedge with a clamp, being careful not to dent it too much.

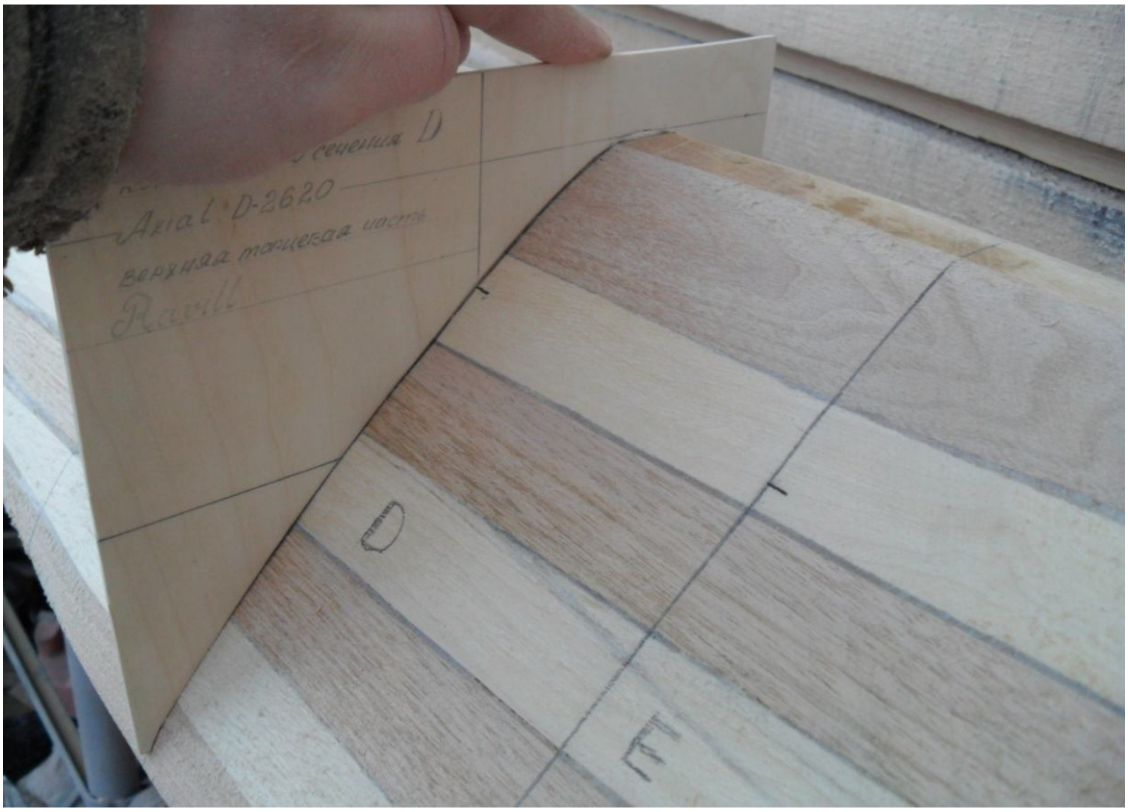
Next, we mark the passage of the center line, applying a square to the side plane of the rule at each section.

For added comfort, use the adjustable square from FIT.



During fine processing, the screw is brought to condition using semi-circular and flat rasps and files L 250-300 mm, with constant checking using control templates.

Fine finishing begins with the working section of the propeller, from the root to the tips. Holding the rasp at a slight angle, thus constantly maintaining an allowance, begin removing excess wood from the trailing and leading edges, shaping the blade's contour.



At the same time, gradually immersing the section template into the blade, controlling its horizontal position and precisely aligning the blade centerline with the template centerline, we create the edge rounding radius. Once the section template reaches its desired depth, traces of the previous steps will disappear completely.

After rasping, a planer is also used for processing. It allows you to quickly achieve a smooth surface over a large area of the propeller blade. Holding the planer by the handles, make long strokes along the blade, covering a distance of 2-3 sections.

When machining the blade, it's also important to constantly ensure that the trailing and leading edges of sections D through K are aligned. For this purpose, use an aluminum level or any other perfectly flat object, placing it against the blade edges.

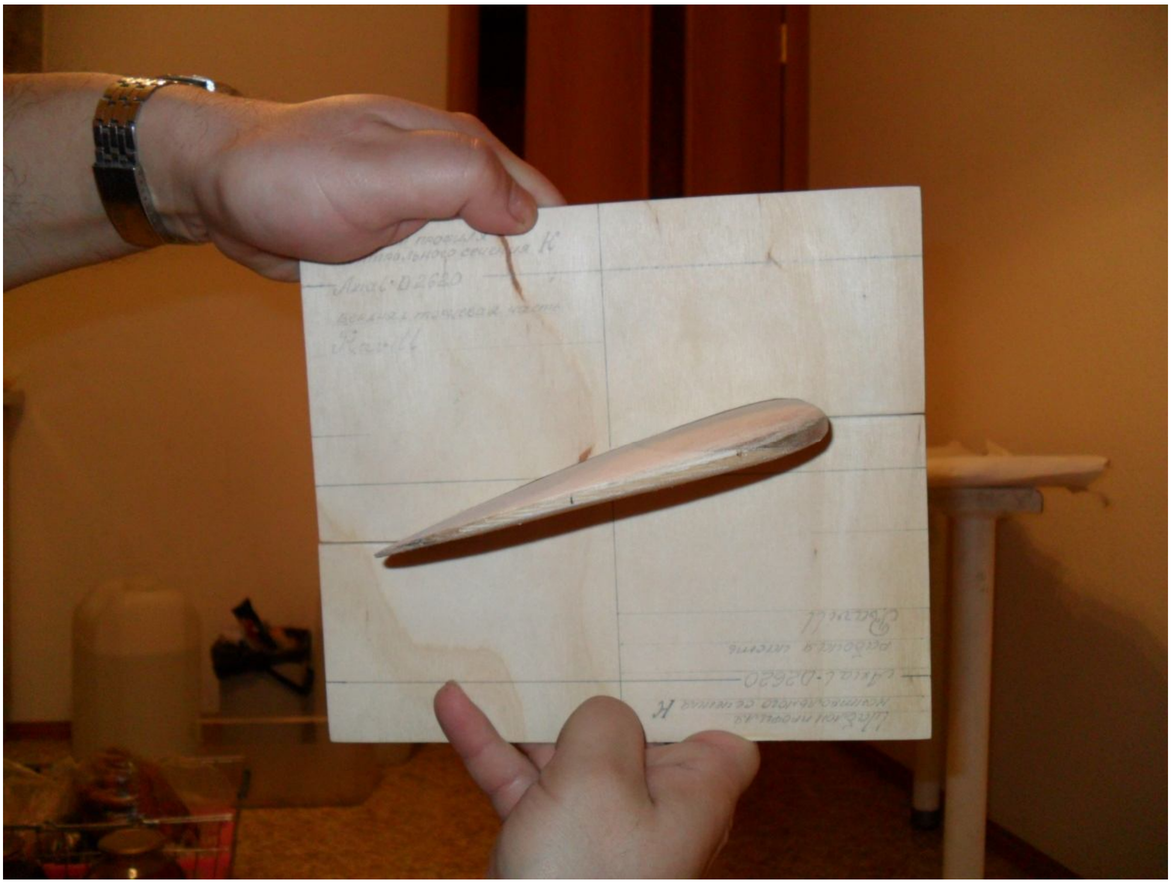
Next, the screw is flipped over, the cross-sections and centerline are marked, and fine finishing of the upper end section begins. Here, significantly more time will be required to finish the leading edge and the convex surface.

The processing begins in a similar manner, first using a rasp at an angle to form the outline of the blade in plan, then moving on to processing the leading edge and then to processing the convex surface.

When cleaning the surface of a wooden screw, the direction of the wood grain should be taken into account; planing, scraping, and sanding should only be done "layer by layer" to avoid scoring and the formation of rough areas.

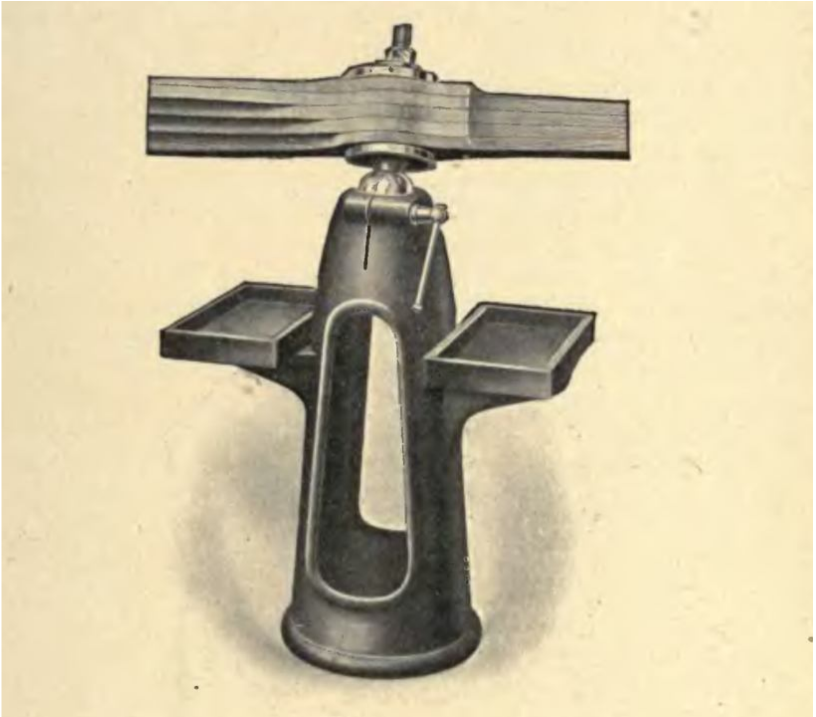
The pitch of the screw also depends on the conformity of the profiles to the drawing, therefore the final processing operation must be carried out with particular care.

At the end of surface processing, the templates of the upper and working parts must be precisely aligned.

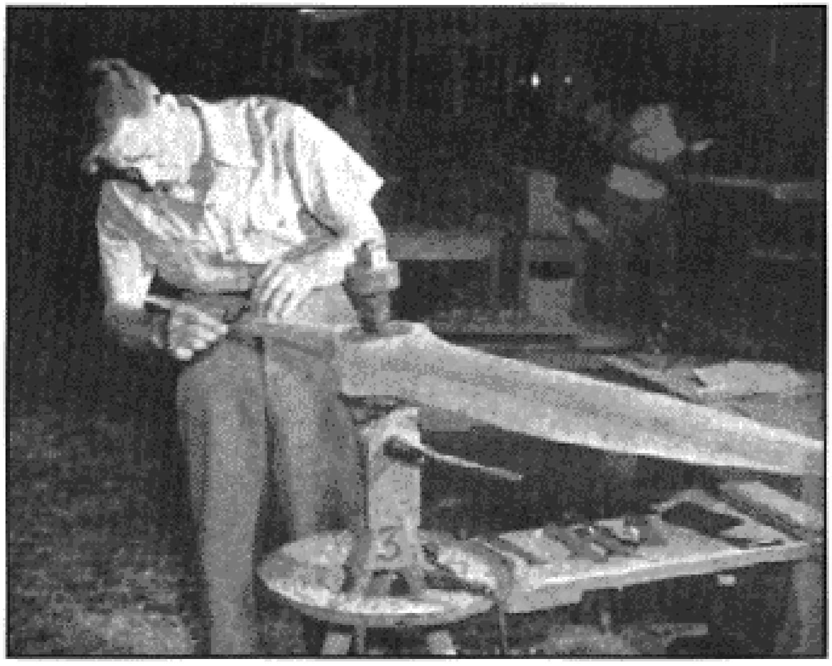


We finish processing with sandpaper of grain size up to P2000.

All processing can be done in any way convenient—on a prefabricated frame or simply on a workbench. Perhaps the most convenient device for this purpose was used in England since the First World War.



This is a special ball stand clamp.

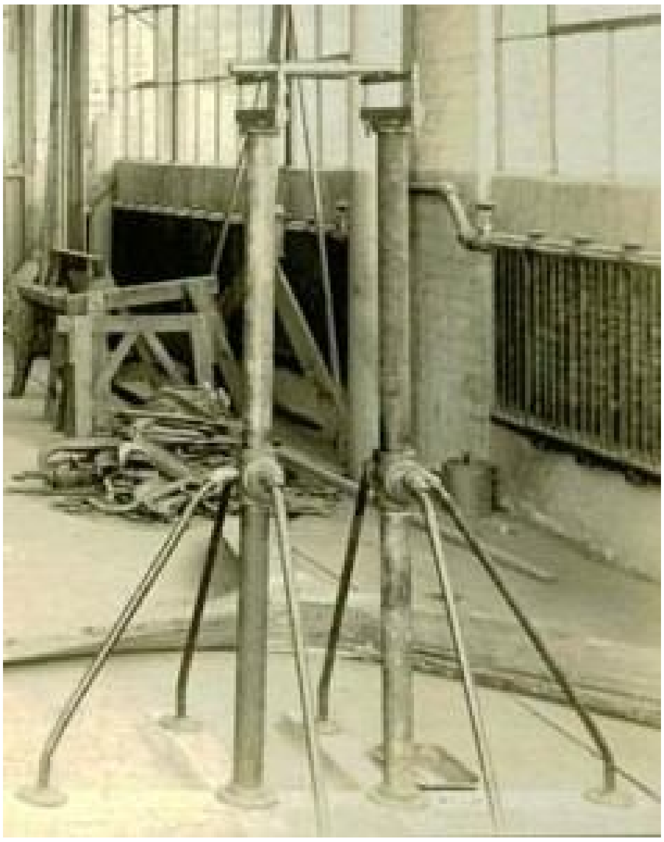


The propeller blank was clamped in it through a hole in the hub for the bushing, allowing the craftsman to tilt it in any position.

Screw attachment

After production, the propeller undergoes a fitting (checking the propeller's symmetry, pitch, and geometric dimensions), which ensures the blades are perfectly matched in weight, shape, and size. Cracks, wood chipping, warping, and the like must be prevented. The manufactured propeller must be carefully balanced, meaning that the blades are perfectly balanced. Precise blade balancing is one of the keys to ensuring uniform and smooth operation after installation on the aircraft. If weight symmetry is disrupted, the engine shaft will be loaded unilaterally during operation, causing the propeller to wobble. Uneven propeller operation will cause vibration and loosening of the fuselage nose mounts. Propeller weight symmetry is checked using a balancing machine (equilibrator).

The equilibrator allows balancing with an accuracy of up to 1 g. If one blade is heavier, it will sink to the bottom.



This simple device typically operates on the same principle: a bearing is mounted on a rigidly fixed shaft, which in turn fits into a screw hole under the bushing. The device can be welded from metal or made of wood.

Experience shows that even with very careful manufacture of the propeller, the weight of the blades is not uniform.

This occurs for various reasons: sometimes due to different specific weights of the butt and top portions of the gorse used to make the propeller, or different layer density, local knottiness, etc. Matching the blades by weight by shaving off a portion of the heavier wood is impossible. In this case, it is necessary to weight the lighter blade. To do this, drill a small hole, insert a lead pellet, and fill it with glue.

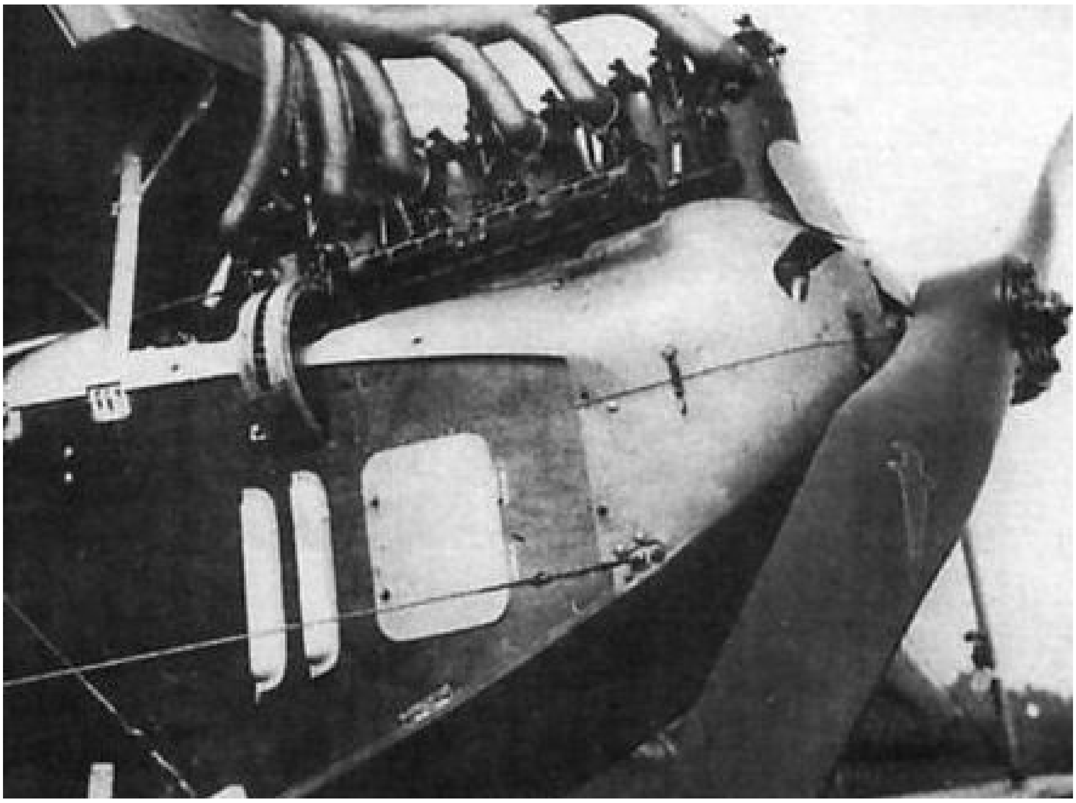
Branding and logos

The next step is to apply a stamp to each propeller blade on the upper end face, indicating: the product number, the name of the propeller AXIAL, the number of horsepower of the engine, the diameter of the propeller, its pitch, sometimes the aircraft designation and the inscription EDULZUG ("Entgegen Dem Uhrzeiger Lauf ZUG")

When striking the stamp, it's important to use the right amount of force—there's no need to strike too hard right away; if the inscription is weak, it's easy to reinsert the stamp in the same place and strike again. After stamping, paint the letters and numbers before varnishing.

After applying the first layer of varnish, AXIAL logos are glued to each blade in a strictly defined location according to the drawing.

Fun fact: Early Axial propellers had a dagger logo - see below.



Varnishing

The finished and carefully balanced propeller must be varnished. Varnishing is necessary to improve flow and protect the propeller from moisture penetration.

Varnish application should also be done on a balancing rig. This will allow you to see the equal amount of varnish applied to the blades if one blade is heavier than the other.

Axial propellers, like many other wooden aircraft parts of the era, were coated with three layers of oil-based marine varnish. In most cases, the oil-based varnish used was Ollak "Prima" from the now-defunct Kronen company. While you won't find the exact same varnish today, a similar varnish can be used.

The final painted surface of the propeller must meet the following requirements: the coating must be free of roughness, scratches, whitishness, dullness and air bubbles.

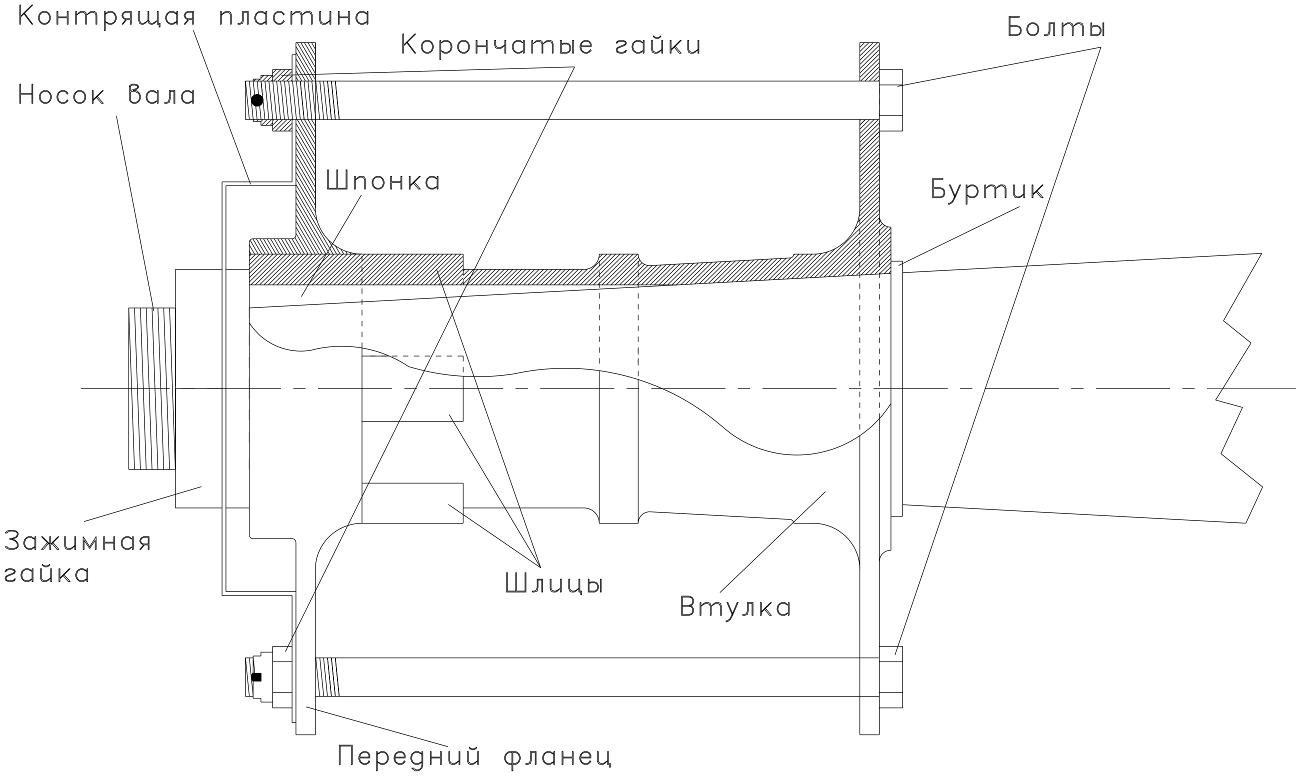
Installing a propeller on an airplane

This operation is already carried out directly at the aircraft factory. The propeller is connected to the engine using a bushing.

The sleeve is inserted into the screw hole, the front flange is put on, the bolts are inserted, the castle nuts are tightened and cotter pinned.

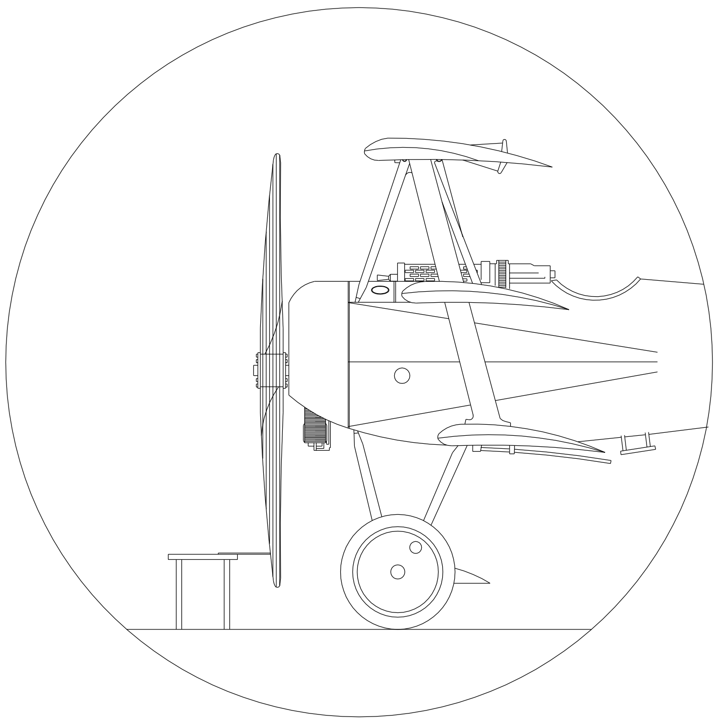
Next, mark the bolts and nuts with red paint. After being inserted into the sleeve, the screw is placed on the shaft nose. The cylindrical portion of the sleeve has a groove along its inner diameter for a key, which secures the screw to the motor shaft.

To secure the sleeve onto the end of the motor shaft nose, an external clamping nut is screwed on, which is locked using a plate pressed across the nut by two bolts.



Oberrursel Ur.II rotary motor bushing assembly

When installing the screw on the shaft, check the correctness of its position relative to the plane of rotation, which should be perpendicular to the axis of the motor shaft.



To check the correct installation of the propeller, it is determined whether each propeller blade will fit equally to the test ruler.

The presence of a large gap between the ruler and the blade indicates the need to place shims (made of brass) under the propeller hub flange.

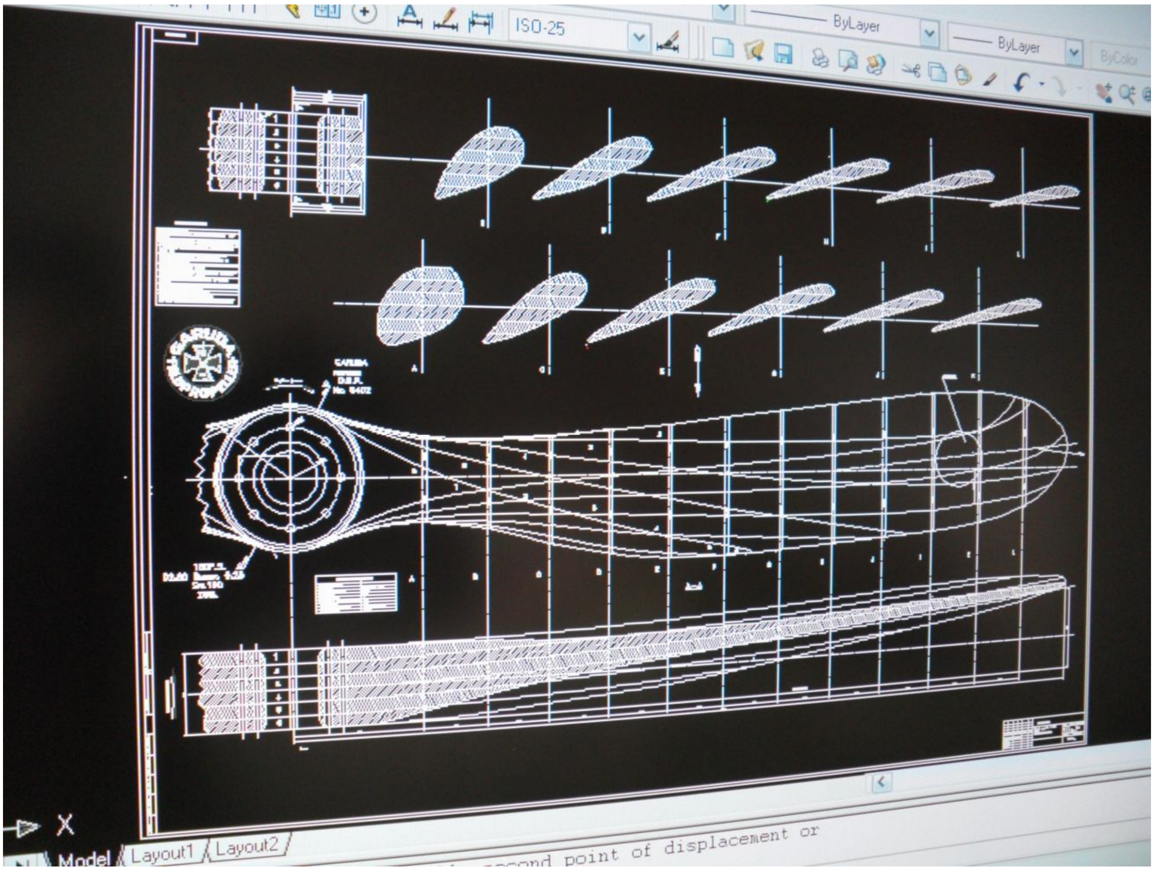
The finished screw should not be stored near heating devices, windows, or on the floor. Such storage may cause it to warp beyond repair.

After installing the propeller on the aircraft, it must be covered and, when stored, turned to a horizontal position.

Appendix. Garuda propeller's next project

Coming soon! Our next project, the Garuda propeller, is exclusive to us. We'll tell you all the secrets of this propeller, including how its V-shape was achieved. What materials were used in its production—our first attempt to recreate the main German propeller used during the First World War.

Screw diameter 2800 mm. pitch 1900 mm.



Dear reader!

Thank you for purchasing our book. Your contribution will enable us to continue our research into early propeller manufacturing technology and replicas.

Please write to us with any suggestions or comments at our email address: Ravill.replica.propeller@yandex.ru

For those interested in early aviation propellers, I also recommend visiting the website:

www.WoodenPropeller.com