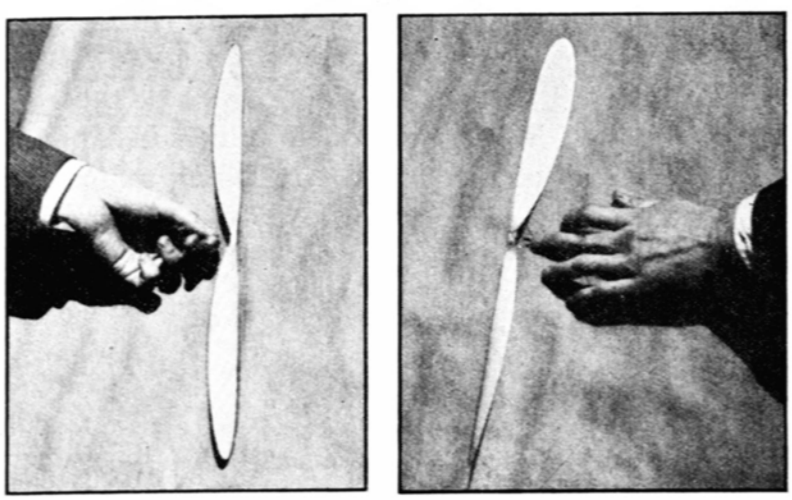
Secrets of Successful Indoor "Prop" Operation

FACTS GLEANED FROM THE EXPERIENCE OF AN EXPERT THAT WILL MAKE YOUR INDOOR PROPELLERS MORE EFFICIENT

By CARL GOLDBERG

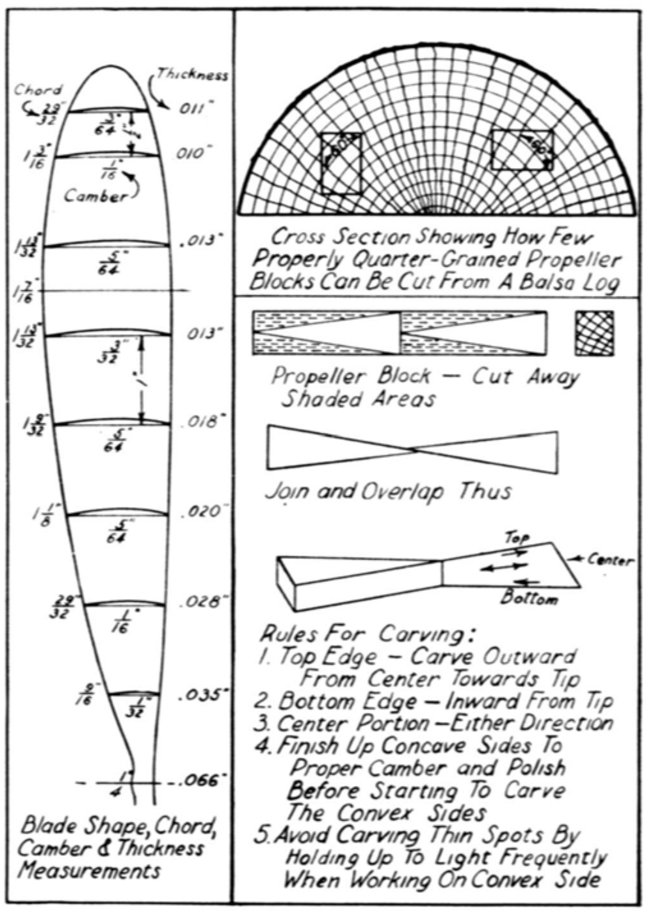
ALONG towards the middle of the summer of 1933, a slim, undistinguished looking 16" propeller was carved for use on a 40" span indoor tractor model. That prop was due to write plenty of model airplane history, but you never would have guessed it to look at it. For the next three years running, 1934, 1935 and 1936, it won the National Indoor Contest. It average winning margin was two minute and thirty-six seconds. Altogether, in competition and out (but mostly in) it has made thirteen flights of twenty minutes or more.



Two views of the efficient indoor propeller described in this article

Consistency seems to be one of the most difficult features to get in a model airplane, so the author decided to study this prop to find out what makes it "bring home the milk" so regularly. The facts that were discovered and the history of development behind it all are being presented here for the benefit of us who feel that the propeller is the most baffling part of copying a record model. At this writing, it still holds the national open record of 23 minutes, 29.3 seconds, established under trying conditions below the 135 foot high roof of the St. Louis arena in 1935.

Naturally, this propeller was the result of years of previous experience with indoor models, particularly of the tractor type. Among the many things which had been learned were the following: the weight of a prop could he kept low by using a fairly high camber to help furnish the necessary strength. The best balsa to use weighed from 4.5 to 5 pounds per cubic foot. Also, quarter-graining was an important strength factor. The finest possible finish had to be employed to cut down the drag: and consequently you find every expert who uses wooden props today spending several hours finishing with 10-0 sandpaper. It is a good idea to spend the last half hour rubbing with the back of the sandpaper sheet, as this packs the surface of the wood, producing still less drag.



The shape of the prop is another very important consideration. Many shapes were experimented with, and they all seemed to prove that the best is one which resembles the outline of a fairly thick wing section such as the Clark Y. It seems that such a shape has the area distributed properly, and is able to produce a large amount of thrust for a small amount of drag.

Experience had also indicated that the best pitch for an indoor prop is about two times the diameter. For example, if a prop is 16" in diameter, its pitch should be about 32". We found that if the pitch were much less than this, the model would have a tremendous climb, but would usually come down with winds still remaining in the motor. This indicated that low pitch is very efficient for climbing, but rather inefficient for the *combined* work of climbing, cruising and coming down. In 1935. an article was published in which it was argued that the best pitch is about 1.3 to 1.5 times the diameter: that is, a 16" prop should have a pitch of 21" to 24". The author happens to know one fact that was not stated: the tests on which this claim was based were climbing tests. No wonder they showed the pitch should be so low! These tests may be all right for outdoor models, where the prop is expected to do nothing but climb the ship: indoors, however, is another matter. Furthermore, the propellers used in these tests were not of the indoor variety either in size or camber.

To get back to the subject, it was discovered that in the summertime rubber motors reached their maximum efficiency and climbed indoor models too high for the available buildings. "Cutback" in the leading edge, right near the hub, was developed to hold down the climb, and at the same time to reduce the great strain of the start of the flight, when the motor delivers its highest torque.

All of these various factors were taken into account in the design of the propeller we are studying. The results immediately were gratifying. One of the test nights stands out as a good example. The model was wound up and launched, and after it had been up several minutes, we all started guessing (from the way it was flying) how much time it would make. The average guess was around twelve minutes, the maximum fourteen minutes. But it fooled us badly and made nearly seven-teen before it finally touched the floor.

Several props similar to this one have been made since by the author, but with slight changes. One had about twothirds as much camber. Another had just as much camber as the original, hut was given 1/4" cutback instead of 1/8". However, even though they had better workman-ship, neither of the new props was as efficient as the old one. The one with less camber appeared to have a poorer climb because of not "gripping" the air, while the prop with more cutback flared too much, so that it turned over very slowly under high power. It climbed very lazily, but since it was the finest of all in workmanship, the climb was continuous. However, it never attained sufficient altitude to "knock off" much duration. Such a prop might possibly be effective on an extremely light, efficient model.

The procedure used in making our 16" tractor prop may well be followed in general, especially on indoor props. First select a clear block of 4 1/2 Ib. balsa. Here is the formula for determining what weight the balsa is. X=108 times weight in ounces / cubic inches. In order to get the number of cubic inches, multiply the block length times the width times the thickness. Find the weight in ounces and fractions on your model scale. Solve the equation for X, and you will have the weight per cubic foot of that particular grade of balsa. For example, supposing you have a block 16xl 1/2x1, and find that it weighs exactly one ounce. Multiplying 16x1 1/2x1 gives 24 cubic inches. The equation then reads X=108 times 1 / 24 ; solving, we have X equals 4 1/2. Therefore, the weight per cubic foot of your block is 4 1/2 Ibs., or just what you want. Incidentally, this shows that a good indoor prop block containing 24 cubic inches should weigh one ounce. Blocks containing more or less cubic inches of wood should weigh in proportion; thus, an eighteen cubic inch block should weigh 3/4 of an ounce, and a 30 cubic inch block should weigh 1 1/4 ounces. The block used in making this particular prop is 16 1/4x 1 9/16x1, and contains 25 cubic inches. Its weight should be just about 1.05 ounces. Next, the quarter-grain lines should be examined. These should run at an angle of about 60° as indicated in the sketch. This will produce the greatest strength about one-third out from the hub, which is where most props tend to bend. Now cut the block into two triangular pieces as shown, and join the two halves over-lapping about 1/4". When dry, push a very fine needle through the exact center of the leading edge perpendicular to the surface, thus forming the hole for the propeller shaft. Rough out the concave side of each blade with your knife, taking at least half an hour per blade. At this time, it is well to remember that one of the tests of an expert is how long he can take on a prop. One should, therefore, take pride in working as slowly as possible, feeling happy as the hours go by.

Try to keep the blades close to one another in their progress; that is, as soon as one stage, such as sanding the camber, is complete on one blade, the other blade should be advanced to equal it. It is poor practice to practically finish one blade while leaving the other in a rough state. One of the two is bound to suffer in workmanship. So let them progress from step to step together.

With medium sandpaper, remove the roughness of carving the camber, and then finish the concave side with 7-0 and 10-0 sandpaper. It is highly important to duplicate the camber exactly as shown at the various points on the drawing. Check the height of the camber at each position by laying a straight edge across the leading and trailing edges, and measuring down to the blade with a fine small steel rule. Near the hub it is especially of great value to have the proper depth of camber. The concave side should take from half an hour to one hour per blade to finish off to a high polish.

Next, rough out the convex side of each blade, using your knife to reduce the thickness of 3/32" at the hub, tapering to 3/64" at the tips. Set the handle of your knife on the edge of your work table, with the blade extending out over the side, cutting edge up. Balance the prop on the knife edge, and it one side is heavy carefully chip off enough to make it just right, testing it several times to make sure. It is practically impossible, of course, to get the prop to balance perfectly on the knife but one can tell closely enough to serve the purpose. Work carefully with the medium sandpaper, balancing the prop every five minutes or so, because you are now starting to thin the blades down to their final thickness. Begin at the tip and gradually thin down about one inch of the blade. Do the same to the other blade, and balance. Then work on the next inch and so on until you get to the hub. One of the best in vestments you can make is to go to your nearest 5 & 10 cent store and buy a small micrometer. You can get one there for 20 cents, and they are surprisingly accurate. After using one on this prop and on other parts such as motor stick blanks, wing spars, et cetera, you'll see what a wonderful help it is in building better models, because you can check things ever so much more carefully. Beyond a doubt, the future will find the micrometer just as important to the indoor model builder as his scale is today; so if you get yours now, you'll be a step ahead of most fellows. In fact, using the scale, the micrometer, and the balsa-testing machine, we have the beginnings of a crude form of stress analysis, which has been dreamed of for years.

The thicknesses given on the drawing are an average of the two blades, since this prop was made before micrometers were cheap and easy to get. Surprisingly enough, there was for the most part very little difference between the two. But it certainly is an eye-opener to study those thicknesses, and see how easily they can be improved. It should be noted that the blades were "miked" at a distance about one-third back of the leading edge; forward of this position the thickness was increased, while closer to the trailing edge it was lessened.

Warp in the thin propeller blades is one of the biggest bugaboos lacing the conscientious model builder. This can be corrected by checking the leading edge every few minutes. Ordinary warp, caused by sanding while holding the blades in an unnaturally bent position, can always be detected by sighting along the leading edge. If this edge appears absolutely straight, no warp is present; but if it has a gentle curve or bend, the warp may be corrected by holding the blade in such a position that the leading edge is straight, and breathing on it from the *inside* of the curvature you are trying to correct. The best thing to do of course is to avoid warp by seeing to it that, as you sand, the blades are not being bent or forced in any way. Local warp or wrinkles are caused usually by sanding a thin spot so fast that excessive heat is generated, swelling the wood and ruining the smooth face of the prop. The safest way is to sand carefully with fine sandpaper when the blade thickness gets below 1/32", instead of using the medium sandpaper to take off all the wood, and merely finishing with the fine. If care is used, no fine scratches need mar the surface of the completed prop. When working on the convex side, the sandpaper should always be used wrapped around a block of very soft balsa. Using a block in this manner always produces a more evenly sanded prop, and after you get used to it, you will find it good for the concave side too. Rest the concave side on top of your left index finger while sanding the convex curve. Never sand it resting on a flat surface, as this will warp and weaken it considerably. It is a good idea to exceed the amount of camber slightly, so that the correct amount will remain after the prop is shaped.

Balance the prop once more, and you will be ready to shape the blades. Use carbon paper to help you make an exact copy of the template shown on the drawing, and trace around the template on the convex side of the prop. If you have a sharp pair of scissors, these will be found very handy for cutting the blade shape: otherwise, use a good razor blade. Finish off the cut edges to a knife-edge with finest sandpaper. Be sure to leave a flat surface in the center of the trailing edge for the washers to bear against. After shaping, continue your careful sanding until the prop reaches a weight of about .015 of an ounce. The finished prop should weigh about .017 complete with shaft and washers. Balance the prop now for the last time, and then bend a hook as shown out of .014 wire for the shaft. Insert it in the prop, and bend the front 1/8" over at a right angle. Cement carefully, trying to fill the hole around the shaft with glue so that it cannot work loose. Do this on both the front and the rear. Next, take two copper or brass washers, 3/32" or 1/8" in diameter, with a hole just large enough to fit well on the shaft, and polish them on an oilstone. Although some may like to use light, very thin washers, it is the author's personal conviction that the more durable type is to be preferred because of smoother running and greater dependability. These can be "stoned" down to a weight of .0007 each. Slip them on the shaft, and then close the hook nearly shut, so that they can't manage to disappear while you're not looking. It is not necessary to glue the forward washer to the prop.

The propeller is now finished, except for one final detail which you may or may not wish to add. To help keep the prop clean, a coat of microfilm solution can be applied to the hub and out along the leading edge for an inch or two on each blade. The additional weight is quite negligible, and is more than balanced by the satisfaction of keeping a well made prop looking fit.

It is always fascinating and sometimes useful to speculate on what the future will bring, what the "next step" should be. For the past several years, it has been the thought of this writer that eventually the most efficient prop will be a double-surfaced microfilm one, with automatic variable pitch. The purpose of the variable pitch device is to keep the blades always working at their most efficient angle, as opposed to the ordinary fixed pitch propeller, in which the pitch that is chosen is really a compromise. To this end, we here in Chicago, especially Sidney Axelrod, who cannot be given too much credit for the unselfish manner in which he gave up many a chance to win contests, have studied and worked for over a year. At a recent meet, Axelrod, who has done all the development work on the designs originated by the author, brought out a 13" prop, double-surfaced with microfilm, and with automatic variable pitch, that weighed only .011 ounce complete with shaft and washers. The best record made thus far with this type of prop, which must be considered as still in its earliest infancy, is the 19 minute flight which won second place for Axelrod in the 1936 Mississippi Valley Indoor Meet.