INSTRUCTIONS FOR USE OF THE KOLL ROTOR PRO, BY LAUREL A. KOLL, DESIGNER

1. OVERVIEW

Perfect blade balance can only be achieved when the blades are of exact equal weight and their center of gravity (CG) is identical. True center of gravity includes the spanwise CG, as well as the chordwise CG. The crux worth of the ROTOR PRO is its ability to establish precise center of gravity equalization between any number of rotor blades--spanwise and chordwise--for both main and tail-rotor blades.

The directions for construction recommended by the manufacturer should be followed carefully. The ROTOR PRO should be used to make these steps easy and assure accuracy. If the blades have plastic or composite reinforcement assemblies that are attached to the blade root, complete this step first for all blades. If you desire to seal the blade ends with cyanoacrylate adhesive (CA) or by other means, this should be done at this time for all blades.

If your blades are supplied with cutouts for weights near the tip, carefully follow the manufacturer's instructions and complete one blade, including fitting (but not gluing) the balsa cover over the installed weight. The purpose of completing only one is that this blade will be the Master and the next blade(s) easily built and matched to the Master using the ROTOR PRO. Do not cover the Master blade at this time. Finish it only to the point of final sanding, prior to covering.

2. BALANCING MAIN-ROTOR BLADES WITH THE ROTOR PRO

The ROTOR PRO should be placed on a clear, level work table at least five feet wide with the threaded rod and zero-balance weight on the side away from you as shown in Figure 1. Adjust the zero-balance weight to a near center position on the threaded rod. It is not necessary that the cradle balances at this stage. If you desire to work on the bottom side of the blades (bottom side facing up), install the positioning arm in the holes in the underside of the cradle from the right side, as shown in Figure 1. The positioning rod has a 3mm and a 4mm diameter pin, perpendicular to the arm. Place the first completed blade (the Master) on the cradle with the blade leading edge against the side nearest you (front side). Insert the proper size positioning arm pin in the blade mounting hole. With the arm lock screw loose, slide the blade and arm assembly on the cradle (as a unit) to a position of near balance and tighten the positioning arm lock screw. This will secure the blade position on the cradle. Adjust the zero-balancing weight until the assembly is in perfect balance, the bubble being exactly centered. Your setup should be like Figure 1. The rod, zero-balance weight and blade position should not be moved again until the spanwise CG for all blades has been completed. *Your goal is to build the other blade(s) on the ROTOR PRO to balance exactly at this same setting.* Once this is achieved, all blades will have the exact same spanwise center of gravity.

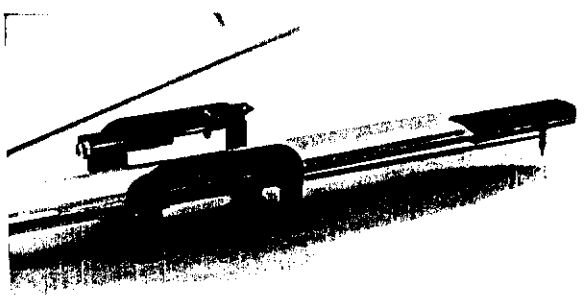


Figure 1
Main Blade Spanwise CG Setup (In the Cradle)

When you have finished balancing the Master, carefully remove it from the cradle and positioning arm without moving the zero-balance weight or arm position, and carefully place the next blade onto the cradle in the same position as the other blade, with the arm pin inserted into the blade pivot hole. Remember to keep the leading edge of the blades against the front side of the cradle at all times.

If you are building weighted blades, place weight in the cutout area of the blade until the

blade comes to balance. The total weight necessary will include all weight, glue, balsa cover strip, etc. The balsa cover strip can be laid next to the cutout area as you work, if desired. If the total weight is too much, after gluing, remove some weight by carefully drilling into the lead weight, or shaving some lead off with a pen knife. Continue to adjust the weight until the blade is in perfect balance at the original setting. Replace the second blade with the Master blade to check the setting to be sure they are the same. When complete, this blade and the Master blade should balance perfectly at the same setting. Complete this with any remaining blades.

If the lead weight is too light and more weight is needed, add more lead or cyanoacrylate (CA). Miniature Aircraft USA has bronze powder (#3709) available that is ideal for this purpose. Simply add the bronze powder to the cutout area as required to bring the blade to balance, and add thin CA to lock it in place. If there is not room in the cutout area, drill a hole(s) near the end of the cutout, in the same plane as the cutout area, and add the bronze powder to the hole(s), secured with thin CA. The bronze powder can be used entirely in place of lead if desired. It can be sanded and worked the same as CA. The bronze powder is extremely easy to use. It has another desirable feature, should a blade strike occur while flying, the bronze powder/CA combination is more likely to disintegrate.

The bronze powder is finely ground and very free flowing. Pouring it from an open plastic bag often results in too much, too quick. Obtain a small plastic dispenser with a tapered spout (such as a one half ounce CA bottle with removable spout). Cut the tip of the spout at an angle with the hole no larger than a small needle (1/32"). This gives complete control of the flow.

If your blades do not have cutout areas for weight, match the second blade to the Master by adding thin CA to the blade, as required, or adding bronze powder as described. The ROTOR PRO will show you where the weight is needed. You simply add it to the high side of the blade (while it is in the cradle) in the amount necessary to zero the bubble. At this point, your blades should have equal center of gravity, spanwise. Before covering, however, the chordwise balance should be checked and adjusted if necessary, and the weight of each blade must be matched. Chordwise balance is the center of balance across the blade chord or the width of the blade perpendicular to the blade span. Chordwise unbalance affects the lead/lag of the blades. The blades generally should track exactly on the same centerline. If the chordwise balance is not the same, the blade will shift toward the light side when rotating, causing the blade airfoils not to be parallel with each other. As with the spanwise balance, the chordwise balance of each blade should match.

3. MATCHING THE CHORDWISE BALANCE OF MAIN-ROTOR BLADES

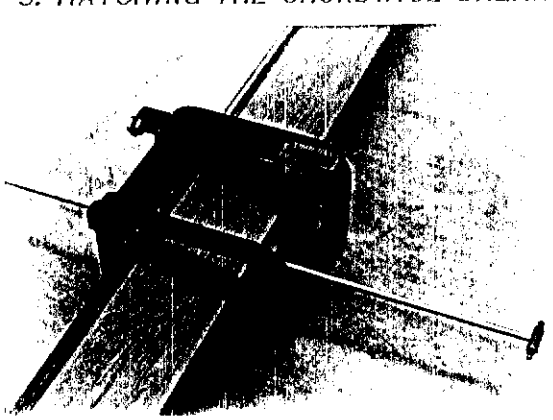
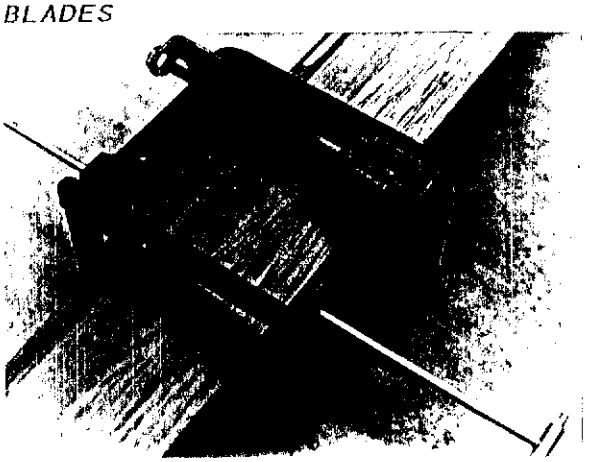


Figure 2
Standard Chordwise CG Setup for 60 Size Blades

There are three (3) settings available on the ROTOR PRO for chordwise CG. The distance between the front of the cradle side openings and the center of pivot is .750". This is the standard for most 60 size blades, as shown in Figure 2. There are two sets of tapped holes near the sides of the base of the cradle. Placing the two phillips head M3 screws in the holes nearest the pivot axis to be



Optional Chordwise CG Setup for 30 Size Blades

used for the leading edge stop, will set the leading edge of the blade .500" from the pivot. The outermost holes set this distance to .625". This allows smaller, 30 size blades to pivot at a point nearer their actual chordwise CG, as shown in Figure 3.

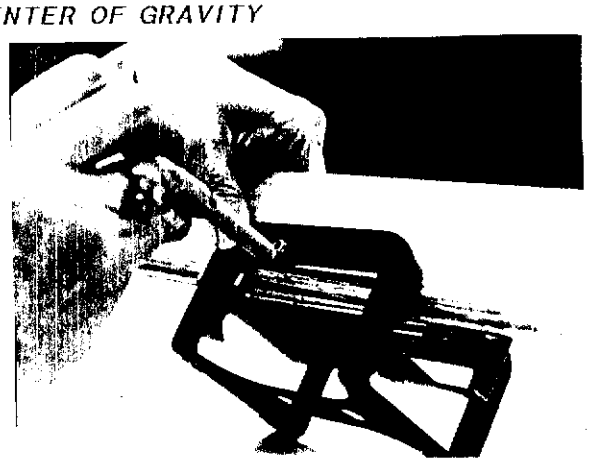
At this point, all blades should be uncovered and have perfect spanwise center of gravity balance. Remove the blade and position arm from the cradle. Insert the tip end of your Master blade through the cradle openings in the sides of the cradle from the front side, with the blade leading edge against the left side of the cradle (or bolts), as shown in Figure 2 or Figure 3. Make certain that the blade leading edge is firmly against both sides of the cradle, thereby, parallel with the pivot axis of the cradle. The blade spanwise CG point should be near the center of the cradle. Adjust the zero-balance weight until the bubble is precisely centered. Check to be sure that the leading edge of the blade is against the left side stops of the cradle once again. Re-balance if necessary. Carefully remove the Master blade from the cradle, without moving the zero-balance weight, and insert another blade. Be certain to insure the leading edge is touching the left side stops of the cradle, as before. If the chordwise center of gravity is equal, the bubble will be centered. If not, weight must be added to the light side of this blade or to the heavy side of the Master blade. It is generally better to shift the chordwise balance toward the leading edge. If this blade has a heavy trailing edge, add weight to the leading edge. If, however, the leading edge is heavy, re-balance the cradle (with this blade) to perfect balance and place the other blade (the Master) back in the cradle. The leading edge of the Master blade will now be high. Add weight to the leading edge side in the amount necessary to bring it to level. Weight can be added to the rear of one blade and the front of the other, if desired.

Adding weight will change the spanwise center of gravity, depending upon where the weight is placed, as well as the blade total weight. Adding the weight necessary near the forward edge of this blade exactly on the center of gravity, would result in both blades having perfect spanwise, as well as chordwise CG. However, we have not yet determined which blade is heavier. If we should add weight to the heavier blade, it will require more weight on the lighter blade to match their total weight. This can probably be done more efficiently by adding the required weight to the lightest blade during the weight matching phase, centered on the spanwise CG. In order to do this, the blades must be first checked for equal weight before installing the weight required to balance them chordwise. At this point, two things should be done: first, the exact center of gravity of each blade must be determined and marked: second, you must determine which blade is lighter. Proceed to Part 4, "Determining and Marking the Exact Spanwise Center of Gravity," and then to Part 5, "Matching the Weight of Each Blade...". When these steps have been completed, return to this section setup and add the weight required to balance the chordwise CG.

4. DETERMINING AND MARKING THE EXACT SPANWISE CENTER OF GRAVITY

Figure 4
Marking True Spanwise CG Through Center Hole

The exact center of gravity of each blade can be marked by first balancing the empty cradle, without the arm, to perfect zero. Place a blade in the cradle with the leading edge against the front side, and carefully



Marking True Spanwise CG Through Side 'V' Notch

position it to perfect balance. The pivot point is the true spanwise center of gravity. Firmly hold the blade against the cradle bottom and lift or tip the cradle and base assembly, together with the blade, and mark a small circle on the blade through the center hole in the cradle base from the underside, as shown in Figure 4.

Alternatively, the blade may be placed leading edge down resting against the front side of the cradle, and marked with a fine soft tipped marker via the 'V' notch in the cradle front side under the pivot bearing, as shown in Figure 5. Repeat this procedure with the other blades.

5. MATCHING THE WEIGHT OF EACH BLADE WITHOUT THE USE OF A SCALE

If you are using a precision scale, you may proceed to Part 7 and then return to Part 6. Balance the empty cradle precisely, with or without the positioning arm. Two blades must be bolted opposite each other with the bolts and washers furnished, as shown in Figure 6. Bolt the blades to the cradle with their trailing edges toward the back side of the cradle. They need only be snug--not too tight. Sight down the trailing edge of the blades and align them so they are parallel with each other. The blades should be as perpendicular to the pivot axis as possible, but this is not as critical as being parallel with each other. Tighten the bolts only tight enough to hold the blades snugly in place. If the bubble is exactly centered, the blades are of the same weight. If not, weight must be placed on the lighter blade, centered on the CG mark, in the amount necessary to bring them to balance (level). The weight can be one weight exactly on the CG or pairs of weights, each equidistant to the CG. The weight should be added on or near the chordwise CG line, or, it can be placed at a position on the blade, chordwise, that will bring the chordwise CG's to match.

Analyze the total condition and you can probably solve two problems with only one addition of weight. In any case, especially if there is any doubt, it is simple to recheck the balance of each blade and precisely determine the exact position where the weight is needed. In most cases, weight can be placed directly on the blade, precisely at the point needed, and this point marked. Then holes can be drilled for lead or bronze powder or CA applied as required. Since the blade is supported at all times, it is extremely easy to determine where the weight must be placed, as well as the amount. Once the blades are level, you have accomplished two crucial things: they are equal in weight, and the center of gravity of each blade is now exact.

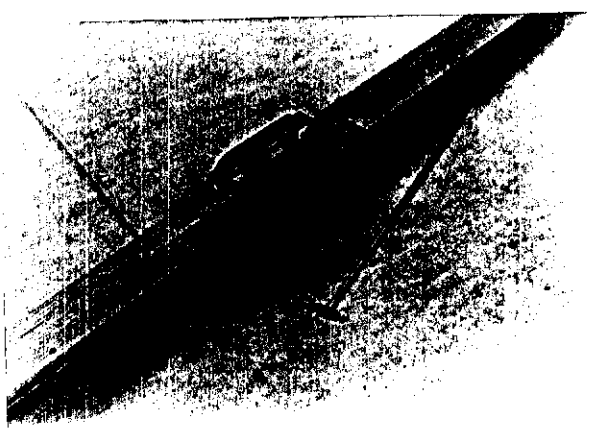


Figure 6
Main Rotor Weight Matching Setup

Once this condition is achieved, the blades are ready for final sanding, before covering. After sanding, blow the wood dust from the blades and recheck the CG of each blade, as well as their matching weight. If one blade is now slightly heavier than the other, a small amount of sanding can be done on the heavy blade to correct this. To assure that the CG remains exact, check the blade that needs sanding against the other blade and sand on the heavy end. Or, if the CG's are correct, the ROTOR PRO will indicate you must sand an equal amount from each side of the CG. No more guessing. Check again to determine if you have sanded correctly.

6. COVERING THE BLADES AND FINAL TRIM

The blade manufacturer's recommendations should be followed when applying the covering. Be certain to clean the wood dust carefully from the wood pores before covering. Dry compressed air is ideal for this, but a clean towel or a tack rag will give good results. This is very important or the covering will not adhere to the blade properly. Either measure and cut the covering exactly the same length for each blade, or apply it at the same point near the blade root on each blade, so that both covers will be of the same weight. Covering will add weight

to the blades, obviously, but it also shifts the center of gravity both toward the tip (spanwise) and toward the trailing edge (chordwise). The shift should be equal, however, on each blade with very little, if any, differential in weight or CG.

Once covered, the blades should be checked again for equal weight. If it is different, the lighter blade should be marked. They should then be checked for spanwise CG. If the CG is correct, the necessary weight must be added to the lighter blade at the pivot point. If the CG is slightly off at this point, the weight necessary to make their weight equal can be added at the point that will balance the blade while it is in the CG cradle. The type of weight used for these small adjustments is usually a narrow strip of covering material or tracking tape. A strip of tracking tape is usually added near the tip of one blade. If this is desired, add it to the lighter end, if any. To keep perfect balance if the blades are of equal CG, a similar strip of white or a contrasting color is added to the other blade at the same spot. These two narrow tracking tapes can usually be cut to a width that will correct any slight weight differential. I personally seldom use tape, preferring to drill a small hole in the underside of the blade where required and adding CA and/or bronze powder. This eliminates any CG shift (there is more tape aft of the chordwise CG) and the blades are smoother. Recheck the weight and CG one final time before flying. It takes only a few minutes, and perfection here is well rewarded by smooth flying.

7. BALANCING MAIN-ROTOR BLADES ON THE ROTOR PRO USING A PRECISION SCALE

If you have access to a precision scale, it speeds up the process by eliminating the weight-matching procedure required without it. A final weight check can be made on the ROTOR PRO when the blades are complete, as shown in Figure 6, just in case the scale that you are using is not precisely accurate. If the blades are not level on the ROTOR PRO, they very likely are not the same exact weight. It's hard to fool mother nature.

One Master blade should be completed as earlier described. This blade is then weighed and the weight recorded. This blade is then placed in the CG cradle using the positioning arm, the balance zeroed, and the arm locked in place, as shown in Figure 1. This blade is then set aside. The next blade is placed on the scale, and the weight required to exactly match the weight of the first blade is added to the scale top with the blade. I generally use small pieces of 1/8" or 3/16" diameter lead cut to length as needed. These can be positioned where needed for balance, when the blade is in the CG cradle, their position marked, holes drilled and the lead CA'd in place, or bronze powder can be used to fill the hole(s). This blade is then positioned on the arm in the CG cradle and the determined amount of weight added where needed. At this point, the blades are of the same weight, but there is only a 50/50 chance that the center of gravity can be matched at this stage. If adding the determined amount of weight at the required point was enough to make them balance, the task is complete.

If however, adding the determined amount of weight was not enough to bring the blade level, it means that the root section of this blade is heavier than the root section of the Master blade. This can be remedied in several ways. Adding enough extra weight to the tip end of this blade to bring it to balance is one way. Once this is done, the blade is weighed again, and the first blade is placed in the cradle. Without changing the balance setting, the same amount of weight that was added to the second blade is now added to this blade at the pivot point to keep them in balance. The CG and blade weight are now identical for both blades.

Check them again on the scale for equal weight and again in the CG cradle for equal center of gravity. Proceed to matching the chordwise center of gravity. As mentioned before, with a little experience, you may want to incorporate the chordwise and spanwise correction into the placement of the required weight. Chordwise weight required can be added at any place along the span to correct the chordwise CG, from root to tip. However, this weight affects the spanwise CG, as well as the total blade weight. Please keep this in mind. It is easy and quick with the use of a precision scale to check both CG and weight. Then you are sure of perfectly balanced blades. Proceed with covering and final checking, as previously described.

8. BALANCING TAIL-ROTOR BLADES: CENTER OF GRAVITY AND EQUAL WEIGHT

As with the main-rotor blades, each tail-rotor blade must be the same weight and have the same center of gravity. If a precision scale is used, mark the heavy blade and record the weights. Without a scale both blades are placed on the ROTOR PRO as described later. The procedure for matching tail-rotor blades is generally the reverse of the main-rotor blades, in that weight is normally removed from the heavy blade rather than added to the light blade.

The ROTOR PRO makes precision matching of the CG of tail-rotor blades extremely easy. There are two 3mm screw holes in the cradle base near the outer edges. Place one of the 3mm cap screws supplied into the left hand hole from the bottom side of the cradle with the threads protruding above the cradle base. Tighten it only to a snug fit. Place one tail-rotor blade on the cradle with the blade-grip mounting hole over the 3mm bolt and the blade tip on the right hand side of the cradle, as shown in Figure 7. The trailing edge of the blade should face the back of the cradle. Position the blade as nearly perpendicular as possible to the pivot axis of the cradle. If you have this correct, the tail-rotor blade is lying across the pivot axis of the cradle. Adjust the zero-balance weight to bring the cradle and blade into perfect balance. Remove the blade. Be careful not to move the zero-balance weight setting. Place another blade in the same exact position and look at the bubble. If they are in perfect balance, the center of gravity of the two blades are equal. If not, weight must be removed from the heavier side of this blade. Weight is generally removed from the root end of the blade, however, as there is more mass in this area. If the tip end of the blade is heavier, re-balance with this blade and remove weight from the root end of the other blade until it balances.

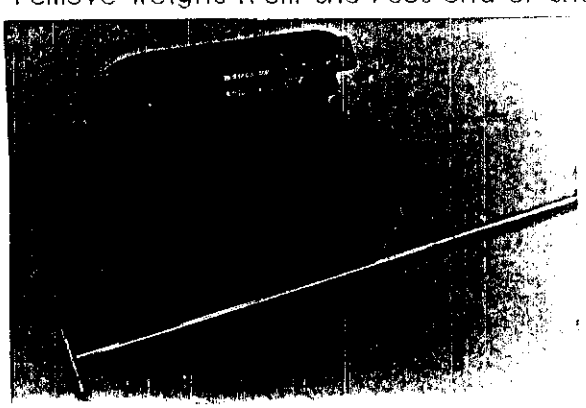


Figure 7
Tail Rotor Blade Spanwise CG Setup

When using the ROTOR PRO to check the blade for matching weight, first place the two supplied 3mm cap screws into each side of the base of the cradle from the bottom side--just snugly. DO NOT OVER TIGHTEN. Zero the bubble to exact balance with these screws in place, but no blades. Place a blade on each screw with the trailing edges facing toward the back of the cradle and the blade tips outwardly opposed to each other, similar to Figure 6. Carefully line up the trailing edges of the blades as nearly perpendicular as possible to the cradle pivot axis. The trailing edges must be parallel. (Note: The bolts may be placed through the blades from the top, if desired. However if sanding is needed, it is easier and quicker if they are placed from the bottom). If the blades weigh the same, the unit will be in perfect balance. If not, the ROTOR PRO shows which blade is heavier (it is the lower blade). Weight generally is removed from the heavier blade, but it must be removed equally from each side of the CG, in order to keep the center of gravity correct. Checking the weight removal in the CG cradle (as it is being removed) will assure removal from the correct area.

If using a precision scale, remove weight from the heavy blade until it matches the weight of the lighter blade. Alternate this blade between the CG cradle and the scale to monitor that it is being removed from the right place and in the right amount. The ROTOR PRO shows precisely where to remove it. Optionally, weight can be added to the lighter blade to accomplish the balance, if desired.

9. BALANCING AIRPLANE PROPELLERS & TAIL-ROTOR HUB AND BLADE-GRIP ASSEMBLIES

Airplane propellers, tail-rotor hub and blade-grip assemblies, and other like devices can be balanced on the ROTOR PRO. The empty cradle should be adjusted to perfect balance. The propeller is placed over the stem of the supplied centering fixture, and the tapered cone is pushed gently into the propeller center hole. The round aluminum base of this assembly is then placed into the center hole in the base of the cradle, as shown in Figure 8. The heavy side, if

any, is the low side. Removing material evenly from the low blade, or adding weight, as needed, to the high side will bring the blades to balance. The blade density of molded, glass-filled plastic is generally near equal, however, one side could have more glass density than the other, or there could be air voids molded into the propeller that are not visible. Wood blades can have different densities such as small knots or open grain. By using the ROTOR PRO, it is extremely easy to check the level, remove the assembly, sand the heavy side, and recheck the level again.

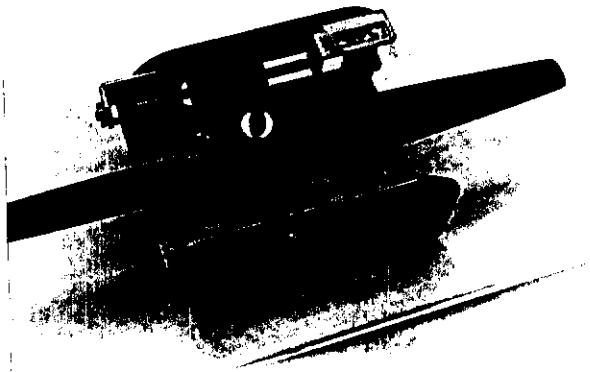


Figure 8
Tail Rotor Hub & Blade Grip Assemblies, Propellers, etc.

Tail-rotor hub and blade-grip assemblies should be checked using this fixture, as in Figure 8. Weight is normally removed from the heavy blade grip. If the hub and blade grips are balanced and the blades balanced for exact CG and weight, the tail-rotor assembly will be in perfect balance. Placing a tail-rotor assembly of hub, blade grips, and blades on the ROTOR PRO as a unit will not give an accurate indication of correct balance unless the blade CG has first been precisely matched. Even then, either the blades or the blade grips could be off. Each assembly should be checked as a unit. A major value of the ROTOR PRO is that it makes determining the center of gravity quick and easy to accomplish and remedy.

10. CHECKING THE BALANCE OF EXISTING BLADES OF ANY TYPE WITH THE ROTOR PRO

The ROTOR PRO is extremely valuable to check existing blades of any type for precise balance, whether they are wood, fiber glass, carbon fiber or other type of construction. Make sure the blades are clean. Place one in the CG cradle, on the arm and zero the bubble, as shown in Figure 1. Remove that blade and place the other blade(s) on the arm in the cradle. It is simple, quick and shows the exact status of the spanwise CG. It is then a very simple matter to slide the positioning arm to a position of near balance, and check the chordwise configuration, as shown in Figure 2.

Chordwise CG is as great or of greater importance than the spanwise CG. If the spanwise CG is not the same, vibration will increase with increased rotor revolutions per minute (RPM). The magnitude of the vibration is related to the force differential created, basically by one blade. If the chordwise CG is off, the blades lead or lag at RPM and the chordwise CG shifts. If you could draw a line through each blades center of mass (weight) in this status, the line would not be centered over the rotor shaft (center of rotation). In this condition, the weight of both blades is orbiting around the center of rotation, creating a much higher magnitude of vibration. Additionally, the blades have unequal lifting characteristics and respond differently to changes in pitch. Perfect chordwise CG is very desirable. With the ROTOR PRO it is now achievable. You can notice a distinct, smooth 'chirping' sound with properly balanced blades (it has been referred to as the "KRP Chirp"), as well as a pronounced increase in performance and autorotation characteristics, not to mention prolonged life of all the components.

Use the ROTOR PRO whenever a vibration problem occurs and have smooth, happy flying.