Radio Control Club of Rochester

four articles to help you get rid of

F L U T T E R

Optimizing Control Surfaces by Geoff Bunion

Control surfaces enable us to maneuver our aircraft and maintain a controlled flight path. Too often these important devices are attached without proper consideration for their function. They can be misfitted, tight and binding, or without sufficient movement. Worse still, they can be laden with surface finishing and attached with loose or sloppy connections that make them flutter candidates. Some ARF air craft have even shown up with no adhesive on the hinges.

Here are some considerations related to aerodynamics, control effectiveness, and aerodynamic flutter.

Ailerons consume some of the wing area and must be fitted to minimize the hinge gap to preserve effective wing area. The best option is to gap seal the joint, but it is not always worth the complexity on the average model. However, if you are working with a high wing loading (greater than 30 oz. per square foot) model, gap sealing is very desirable to stabilize the low speed environment. Gap sealing will reduce the aerodynamic drag and increase the control effectiveness, thus requiring less deflection for the same outcome. A simple gap seal can be achieved by laying a strip of adhesive tape over the joint while holding the control surface at full deflection to preserve its movement. Such a seal will require replacement from time to time as it will degrade during service.

Stabilizer control surfaces are not required to be snug-fitting unless you are dealing with a fast and slippery model. In some circumstances it is desirable to open the gaps to reduce control sensitivity. This may be the case on a training model. Some trainer type models have a huge control surface gap on the rudder and elevator. The purpose of this gap is to provide a soft feel around the neutral position and a strong control response toward full deflection which results in the gap closing. This control response is analogous to an exponential-type movement available on most computer radio transmitters.

Control surface flutter is the curse that will destroy your model quicker than you can say "what's that noise?" Flutter is caused by a lack of balance of the control surface about its hinge point. In smaller models, it is hardly ever evident due to the low mass of the surfaces. However, the larger the model and the more surface finishing materials used (fillers, primers, and paint) the more susceptible the surface is to flutter. If the surface is susceptible to flutter, then it is only a matter of speed before the flutter happens and structural failure becomes eminent. **It is commonly believed that removing control system slop and stiffening the control linkage will eliminate flutter. This is not true**. It will only defer it to a higher speed. The only solution to control surface flutter is to mass balance the surface (add mass to the control surface ahead of the hinge line to achieve a balanced condition). If you identify flutter and survive to rectify the problem, then you can consider yourself very fortunate. Many have never been able to identify the cause of their model's demise or been able to recover from the situation.

from Vapor Thies, Fred Harvey, editor 307 N Brook Forest Rd Derbv KS 67037

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FLUTTER? WELL, SIR, flutter is what a flag does wildly on the flag pole on those days when it is too windy for you to fly. But to better relate it to our subject, it should be described as a potentially destructive vibration or buffeting of an aircraft due to an out-of-balance condition of one or more of its control surfaces.

Now, imagine one of your control surfaces acting like a flag in the breeze . . . in flight at 100 or 200 mph. How long do you think it would stay with the airplane? Not for long, I'll wager!

Most of us are aware that the flutter problem is a complex one and it has been around aviation for a long time. So long that flutter specialists must be wallowing around knee deep in the accumulation of flutter fodder generated from years of research and testing. Fortunately, there are a few useful assumptions and certain recognized `good practices' which have been sifted out and any builder willing to apply the guidelines can do much to avoid having a flutter problem. But before I continue, let me discuss a few terms and phrases.

Static Balance
Static balance - A condition that exists when an object (wheel, propeller, control surface, anything) remains stationary while supported on, or suspended from its own center of gravity. Relating this more specifically to our subject, it also means balancing a control surface while it is at rest (not in flight). Automobile wheels, as you know, can be balanced statically (while at rest). A more effective way, however, is dynamic balancing (spin balancing). The dynamic balance of aircraft surfaces is similarly effective but homebuilders really have no practical way of working out the dynamic balance of a control surface subjected to the stresses of flight. For this reason, they must fall back on what might be called a `good practices concept' and assume that, for all practical purposes, when a control surface is properly mass balanced in its static condition, it should also be in dynamic balance. If, in principle, the main objective of dynamic balance is to prevent or minimize torsional stress in flight, we can accomplish this adequately by evenly distributing the mass balance weight along the span of the control surface.
Broadly speaking, to attain a static balance state in a control surface, we add lead weight to the nose until the center of gravity falls on the hinge axis. Let me expand on this a bit.
For example, if you were to suspend a control surface from its hinge axis, one of three static balance conditions would become immediately apparent to you.
1. If the control surface assumes a trailing-edge-low attitude, it is statically underbalanced and a tail-heavy condition exists.
2. If the control surface remains in a level (horizontal) attitude, it is said to be statically 100% balanced and its center of gravity (cg) is co-located with the hinge axis.
3. Should the trailing edge of the control surface rise some position above a horizontal plane, an overbalance condition is apparent.
Two of the three conditions described above result in a control surface that will have a fairly predictable flutter-free flight performance. The one that is 100% balanced to a level attitude should consistently give good results. The other surface having a slight nose down attitude is a typical overbalance condition essential for good results in high-performance aircraft. Conversely, the static underbalance, or tail heavy condition first described, is the least desirable as it may result in unpredictable flight performance.
The conventional flap type (aileron, elevator, rudder) control surface, as constructed, is typically tail-heavy. That is to say, most of its structure is distributed behind the hinge axis. It is this sort of tail-heavy out-of-balance condition that is generally considered to be the major cause of control surface flutter and buffeting incidents. True, speed through the air is also a factor and there is no doubt that flutter is a more frequent occurrence in high performance aircraft than it is with the slower varieties. However, it would be dangerous to assume that slower homebuilts are immune from such a propensity. I'll bet you have heard many times that homebuilts having cruising speeds under 150 mph were exempt from the flutter problem. Don't you believe it! Any airplane can experience flutter . . . even your light and slow VW-powered job under certain conditions.

Does this mean that you must balance the control surfaces of your project even though the plans don't call for it? Not at all. Undoubtedly the prototype of the airplane you are building was built and flown without having exhibited flutter tendencies and the designer, therefore, found no need to require static balancing of the control surfaces. However, you should understand that, although many other examples of this same design may have been built and flown, there is no assurance that yours will likewise be free of flutter problems.

The only way you can prove your airplane to be free of flutter tendencies is to flight test it with that purpose in mind. This is a potentially dangerous adventure and must be done only under carefully controlled conditions. You must prove that your airplane is controllable, free from flutter, and will be safe to fly. No amount of reassurance derived from theoretical calculations can substitute for this requirement.

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Other Flutter Provoking Conditions

Although there is less risk of encountering flutter in slower aircraft than in high performance types, individual builders can cause changes, inadvertently, which could introduce flutter tendencies. For example, a wing lacking torsional rigidity could induce a bad case of aileron flutter even at the relatively low airspeeds generally associated with low and medium-performance aircraft.

A newly constructed aileron or elevator that is excessively heavy (due to the use of heavier substitute materials or uncalled for reinforcements) can be flutter-prone. Flutter is most difficult to suppress in very large or heavy control surfaces and the balance weight requirement becomes excessive.

Would it surprise you to learn that even time-tested production-line aircraft are not immune to the flutter phenomenon? True! The reason being that anytime anything changes the balance of the control surfaces it may induce flutter in an aircraft that has had no history of such tendencies. For example, there have been instances where flutter developed simply because mud adhered to the control surfaces following muddy field operation.

In an incident reported by the FAA, moisture had collected inside the ailerons during winter operations and had frozen (seems to happen every winter) thereby causing an unbalanced condition that was not detected during the preflight . . . result? In-flight flutter and an accident.

During the long days and nights in the life of an aircraft many changes take place. Dirt accumulates inside the control surfaces, patches are added to repair dings and tears, and in time, the surfaces are repainted. All of these things cause a cumulative change in the mass balance of the control surface. At some point, the amount of change becomes just too much . . . and increases the risk of flutter if no steps are taken to rebalance the reworked surface.

Loose balance weights, water absorption in foam structures, improperly located or clogged drain holes are all elements which could contribute to an aerodynamic imbalance situation and result in flutter.

Avoid free play or slack in the control cables. Stiffness in the control system does have a useful damping effect on the control surfaces further inhibiting flutter tendencies. However, this should not be completely relied upon as later, in service, the wear and occasional lubrication could free the system of much of its original friction and result in an increased risk of flutter.

Adding a fixed trim tab to an aileron can further upset a marginal balance condition.

Controllable trim tabs, too, can be a problem. Trim tab control linkage failures and trim tabs with loose or improperly installed and adjusted linkages have caused a considerable number of accidents and near accidents by exciting flutter in the control surfaces to which they are attached. A recent incident of that nature has just come to my attention. Involved was a widely built and proven design . . . the staid ol' Emeraude. Here's how it happened.

Flutter . . . A First Hand Account

"I knew the trim wasn't working - but who needs trim for a ten minute every-which-way hop! I'm not one for flying level long, so we went into a turning dive -somewhere over 140. All hell broke loose and I about lost control . . . elevator flutter - it was violent! Honest, each wing and the whole tail was shuddering.

I came off the power . . . leveled my wing . . . very hard to do, and started looking for a place to dump her. About 90, the flutter slowed but still bad - at 80 it quit!

I kept my head, let her glide for a few seconds and then added power - kept my nose high and flew back to the airport but slow - making shallow turns and a long straight in to a God awful landing - but safe!

Once on the ground I found the problem - the trim tab. Suddenly I remembered. Earlier a boy and his dad were visiting with me while I was working on my brakes. The boy was in back playing with the elevator. He must have bent the tab control wire - leaving the tab to start fluttering at high speed - thus causing the elevator to flutter.

It took two minutes to fix the cable. I checked for other damage - none. She is an awful strong design, that Emeraude. It took a little longer to get up enough guts to fly her again, but I did the same day.

She's fine now but I have a little more respect for small items. I also preflight a little more carefully now. I don't know if you have ever experienced flutter or really know what it's like - I'm afraid of it now."

There are not too many folks around who can tell you, first hand, how sudden and destructive control flutter can be. We do know it can happen and does happen all too often. This gent was lucky. He had a good stout airplane and did just the right thing

Control Surface Flutter Problems, Sport Aviation 7/79, By Tony Bingelis

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FAA AC 43.13-1B 4-36. FLUTTER AND VIBRATION

PRECAUTIONS. To prevent the occurrence of severe vibration or flutter of flight control surfaces during flight, precautions must be taken to stay within the design balance limitations when performing maintenance or repair.

a. Balance Changes. The importance of retaining the proper balance and rigidity of aircraft control surfaces cannot be overemphasized. The effect of repair or weight change on the balance and center of gravity is proportionately greater on lighter surfaces than on the older heavier designs. As a general rule, repair the control surface in such a manner that the weight distribution is not affected in any way, in order to preclude the occurrence of flutter of the control surface in flight. Under certain conditions, counter-balance weight is added for-ward of the hinge line to maintain balance. Add or remove balance weights only when necessary in accordance with the manufacturer's instructions. Flight testing must be accomplished to ensure flutter is not a problem. Failure to check and retain control surface balance within the original or maximum allowable value could result in a serious flight hazard.

b. Painting and Refinishing. Special emphasis is directed to the effect of too many extra coats of paint on balanced control surfaces. Mechanics must avoid adding additional coats of paint in excess of what the manufacturer originally applied. If available consult the aircraft manufacturer's instructions relative to finishing and balance of control surfaces.

c. Trapped Water or Ice. Instances of flutter have occurred from unbalanced conditions caused by the collection of water or ice within the surface. Therefore, ventilation and drainage provisions must be checked and retained when maintenance is being done.

d. Trim Tab Maintenance. Loose or vibrating trim tabs will increase wear of actuating mechanisms and hinge points which may develop into serious flutter conditions. When this happens, primary control surfaces are highly susceptible to wear, deformation, and fatigue failures because of the buffeting nature of the airflow over the tab mechanism. Trailing edge play of the tab may increase, creating an unsafe flutter condition. Careful inspection of the tab and its mechanism should be conducted during overhaul and annual inspection periods. Compared to other flight control systems on the air-craft, only a minor amount of tab-mechanism wear can be tolerated.

(1) Free play and stiffness may best be measured by a simple static test where upward and downward (or leftward and rightward) point forces are applied near the trailing edge of the tab at the span-wise attachment of the actuator (so as not to twist the tab). The control surface to which the trim tab is attached should be locked in place. Rotational deflection readings are then taken near the tab trailing edge using an appropriate measuring device, such as a dial gauge. Several deflection readings should be taken using loads first applied in one direction, then in the opposite. If the tab span does not exceed 35 percent of the span of the supporting control surface, the total free play at the tab trailing edge should not exceed 2 percent of the tab chord. If the tab span equals or exceeds 35 percent of the span of the supporting control surface, the total free play at the tab trail-ing edge should not exceed 1 percent of the distance from the tab hinge line to the trailing edge of the tab perpendicular to the tab hinge line. For example, a tab that has a chord of 4 inches and less than or equal to 35 percent of the control surface span would have a maximum permissible free play of 4 inches x 0.020 or 0.080 inches (total motion up and down) measured at the trailing edge. Correct any free play in excess of this amount.

(2) Care must also be exercised during repair or rework to prevent stress concentration points or areas that could increase the fatigue susceptibility of the trim tab system. Advisory Circular (AC) 23.629-1A, Means of Compliance with Section 23.629, Flutter, contains additional information on this subject.

NOTE: If the pilot has experienced flutter, or thinks he/she has, then a complete inspection of the aircraft flight control system and all related components including rod ends, bearings, hinges, and bellcranks must be accomplished. Suspected parts should be replaced.

4-37. LOAD FACTORS FOR REPAIRS. In order to design an effective repair to a sheet metal aircraft, the stresses that act on the structure must be understood.

a. Six types of major stresses are known and should be considered when making repairs. These are tension, compression, bending, torsion, shear, and bearing.

b. The design of an aircraft repair is complicated by the requirement that it be as light as possible. If weight were not critical, repairs could be made with a large margin of safety. But in actual practice, repairs must be strong enough to carry all of the loads with the required factor of safety, but they must not have too much extra strength. A joint that is too weak cannot be tolerated, but neither can one that is too strong because it can create stress risers that may cause cracks in other locations.

4-38. TRANSFER OF STRESSES WITHIN A STRUCTURE. An aircraft structure must be designed in such a way that it will accept all of the stresses imposed upon it by the flight and ground loads without any permanent deformation. Any repair made must accept the stresses, carry them across the repair, and then transfer them back into the original structure. These stresses are considered as flowing through the structure, so there must be a continuous path for them, with no abrupt changes in cross-sectional areas along the way. Abrupt changes in cross-sectional areas of aircraft structure that are subject to cycle loading stresses will result in stress concentration that may induce fatigue cracking and eventual failure. A scratch or gouge in the surface of a highly stressed piece of metal will cause a stress concentration at the point of damage.

a. Multirow Fastener Load Transfer. When multiple rows of rivets are used to secure a lap joint, the transfer of stresses is not equal in each row. The transfer of stress at each row of rivets may be thought of as transferring the maximum amount capable of being transferred without experiencing rivet shear failure.

b. Use Of Stacked Doublers. A stacked doubler is composed of two or more sheets of material that are used in lieu of a single, thicker sheet of material. Because the stress transferred at each row of rivets is dependent upon the maximum stress that can be transferred by the rivets in that row, the thickness of the sheet material at that row need only be thick enough to transfer the stress applied. Employing this principle can reduce the weight of a repair joint.

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FLUTTER by Ted Cannelongo

Many times when I have been to the flying field I have noticed many models flying with a buzzing sound also known as flutter. More recently one of these models was my own. Usually this sound seems to occur only when flying at high speed, bull think that the problem may exist at low speed, only it is less severe and no longer loud enough to be heard.

As many of you may already know, flutter can be a serious problem to correct because the cause is very difficult to find. Some modelers, unsuccessful at solving the problem, just continue to fly the model and "let it buzz". Some modelers simply fly the model at slower speed to minimize the effects, accepting the problem as 'unsolvable'.

After talking with a model manufacturer by phone and researching through model aviation magazines, books and model assembly instruction booklets, I assembled a check list of possible causes of flutter.

I want to share this information with those of you not already familiar with the causes and consequences of flutter. Hopefully, I can save some of you a little grief and possibly help you prevent an accident.

Control surface flutter is generally indicated by a low frequency buzzing sound. If, when flying a model, you hear this sound, land the model immediately. This is because flutter can QUICKLY destroy the components of your airplane. As we all know, deterioration of any one component can (and probably will) result in a crash. Find the cause of the problem and correct it.

If It Fluttered Once, It Will Flutter Again!

Continuing to fly a model with flutter is asking for an accident 10 happen. If you must "test fly" the model after attempting to cure the problem, try to keep away from the pit and spectator area or "test fly" during off-hours when there are few people at the field. If the model vibrates apart and crashes, you don't want it to come down in a populated area of the field. First check the servo mounts for deterioration. This is often said to be an indication of which surface is causing the flutter (imagine what this does to your servo!). If this is not successful, here are some things that are known to cause flutter:

1. Pushrod stop or flexing of the linkage.
2. Play in the clevis pin at control horn attachment Replace the horn or use a different hole that allows no play.
3. Play in the clevis pin at the servo arm attachment. Replace the servo arm or use another hole with no play.
4. Sloppy Z-bend fit in servo or servo arm hole too large. Replace the servo arm or use another hole with no play.
5. Control horns not solidly mounted. Use CA to harden the wood. Be sure screws are secure.

6. Side play of plastic pushrod caused by tight bends. Reroute the pushrod.
7. Elasticity present in flexible plastic pushrods. Use heavy duty flexible rods, wood or fiberglass pushrods. Don't use any bend in control wire over 30 degrees.
8. Improperly mounted flexible pushrods (insufficiently supported along the center portion). Flexible pushrods must be secured at increments along the entire length, not just at the ends.
9. Poorly glued aileron torque rod. Drill proper size hole and use sufficient epoxy where the torque rod goes into the aileron wood.
10. Poorly glued elevator joiner wire. Drill proper size hole and use sufficient epoxy.
11. Excessive hinge gap. Remove hinges and reinstall with less gap and/or iron on a plastic film strip to seal the gap.
12. Aileron flex due to wood which is too soft. Build and install new stiffer ailerons.
13. Not enough or insecurely fastened hinges.
14. Hinges installed too far from the end of control surfaces. Install hinges according to the plans.
15. Excessive play (backlash) in servo gears. Replace servo or install new gears.
16. Poor (insecure) servo mounting. Remount according to the manufacturer's instructions.

Using the above guide as a check list, I solved the flutter problem in my model. I had drilled out the holes in the aileron servo arm to make it easier to install the Z-bend rods. I had drilled them too large allowing a fraction of a millimeter of play in the linkage. Simply drilling the proper size hole in a replacement servo arm solved the problem. I couldn't believe only a fraction of a millimeter of play could cause such flutter if I didn't see it myself. I was reminded that attention to the smallest details is important in building a model that is safe and fun to fly.

(from Flight Lines, Gary Thompson, Editor, 2245 Village Green Parkway, Chesterfield, MO 63017)
(from The Pilot Log, Niagara County Radio Controlled Model Flying Club, Lockport NY March 2003)

Historical Development of Aircraft Flutter

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AEROELASTICITY, and in particular flutter, has influenced the evolution of aircraft since the earliest days of flight. This paper presents a glimpse of problems arising in these areas and how they were attacked by aviation's pioneers and their successors up to about the mid-1950s. The emphasis is on tracing some conceptual developments relating to the understanding and prevention of flutter including some lessons learned along the way. Because it must be light, an airplane necessarily deforms appreciably under load. Such deformations change the distribution of the aerodynamic load, which in turn changes the deformations; the interacting feedback process may lead to *flutter,* a self-excited oscillation, often destructive, wherein energy is absorbed from the airstreams. Flutter is a complex phenomenon that must in general be completely eliminated by design or prevented from occurring within the flight envelope.

The initiation of flutter depends directly on the stiffness, and only indirectly on the strength of an airplane, analogous to depending on the slope of the lift curve rather than on the maximum lift. This implies that the airplane must be treated not as a rigid body but as an elastic structure. Despite the fact that the subject is an old one, this requires for a modern airplane a large effort in many areas, including ground vibration testing, use of dynamically scaled wind-tunnel models, theoretical analysis, and flight flutter testing. The aim of this paper is to give a short history of aircraft flutter, with emphasis on the conceptual developments, from the early days of flight to about the mid-1950s. Work in flutter has been (and is being) pursued in many countries. As in nearly all fields, new ideas and developments in flutter have occurred similarly and almost simultaneously in diverse places in the world, so that exact assignment of priorities is often in doubt. Moreover, a definitive historical account would require several volumes; yet we hope to survey some of the main developments in a proper historical light, and in a way that the lessons learned may be currently useful. It is recognized that detailed documentation of flutter troubles has nearly always been hampered by proprietary conditions and by a reluctance of manufacturers to expose such problems.

From our present perspective, flutter is included in the broader term aeroelasticity, the study of the static and dynamic response of an elastic airplane. Since flutter involves the problems of interaction of aerodynamics and structural deformation, including inertial effects, at sub critical as well as at critical speeds, it really involves all aspects of aeroelasticity. In a broad sense, aeroelasticity is at work in natural phenomena such as in the motion of insects, fish, and birds (biofluid-dynamics). In man's handiwork, aeroelastic problems of windmills were solved empirically four centuries ago in Holland with the moving of the front spars of the blades from about the midchord to the quarter-chord.