GUSSETS
THEIR PURPOSES, FORM, AND APPLICATION RECOMMENDATION

From the September/October 2001 Flying Aces Club News, Lin Reichel, Editor
(Ed. Note: Your friendly editor, know in these parts as "wrinkles" White, is visibly smarter after reading this)

DEFINITION: For the purpose of this article a gusset is a brace that forms a triangle or a shape with 3 sides, which may not be straight e.g. rudder and wing tip curves.

PURPOSE: Some ***conceptual*** applications of gussets are to:
Strengthen an angular joint to resist shear stress,
Strengthen an angular joint to resist tension stress,
Assist dihedral bracing,
Oppose swaying in a non-triangular cell,
Assist in the transmission of torque from something like a spar to rib or cross member,
Brace outside corners and sharp bends against bending caused by tissue tension.

Of these applications, the bottom two were tested for their contribution in the reduction of warps and wrinkles.

The reason the word conceptual is used above is that what we think may be a good idea is not proven to be when tested in real situations. I tested the first conceptual application (Torque transmission) with 3/32 square members glued at 90 degrees and again with 1/16 square members configured in the same way. One member, we'll call the torque arm, was glued as a butt joint to the other, which we'll call the torque rod. I clamped the torque rod on consecutive trials at 4, 3, and 2 inches from the glue joint. The torque rod was supported past the glue joint (on the end opposite the clamped end so that it would not bend down when a load was placed on the torque arm. In all cases the torque was arm was bent to an angle of 10-degrees. This was an angle greater than any I anticipated a structural member, such as a spar, would be asked to take. In all cases the butt joint did not break. The wood used was 10-pound density. It was assumed that lighter wood would be easier to twist and therefore the joint would hold. This was supported after testing the 1/16 square members using 6-pound wood. Now the above applies to a 90 degree joint with the torque arm of the same cross section as the torque rod. If these conditions are not met then a gusset may be needed. An example is using a torque arm of less cross sectional area e.g. (I /32 X 1/16th) or when it is glued to the end of the torque rod. Also if the angle the arm makes with the rod is not 90 degrees it may be hard to make a good joint. An application where these conditions (thin torque arm and angle other than 90 degrees) are met is the internal diagonal brace as in some stabilizer and wing structures. In this situation the joint of the arm with rod is critical and a solid gusset may be necessary. The gusset in this type of situation can be quite small and may be considered a fillet rather than a gusset. I don't know when one turns into the other.

It is well known that gussets in outside corners or curves in such places as wing tips can reduce or eliminate wrinkles. But exactly where do they need to be placed and what is the best shape for them? I have found that they need to be placed at the corners of any place where tissue is glued down to the corner members. So if the tissue is glued down for example through out the stabilizer to cross members and a center spar then gussets will be needed at all these joints. Other typical places are the wing roots, or dihedral joints, tail end of the fuselage, fin leading edge (vertical stabilizer) to its base, etc. Some times the gusset at the dihedral joint is serving not only as a brace against tissue tension but also a dihedral brace. As a result a flat triangle in the plane of the bottom of the wing would be inadequate. A surface that matches the top of the wing is also needed to brace against a lift load. The easiest way to provide both of these surfaces is to make a solid block and shape it to conform to the cross sectional shape of the wing. An alternate is to place in these corners a sheet that is thick enough to be shaped to match the rib.

How does this brace which forms a triangle reduce or eliminate wrinkles. It does it by preventing the edge to which the paper is glued from being bowed by the tension of the paper. Another way it may help is by preventing a cell say with 90-degree corners from deforming to a parallelogram without 90-degree corners. (See Kris Starleaf's Yak-3 plans of how this could work on a rudder) At a corner the paper is pulling from both directions. The magnitude of the pull is a function of the grain orientation and length of the paper relative to the direction of shrink. Paper shrinks more at right angles to the grain, but the direction parallel to the grain is typically the longest so that magnitude of shrink is also important. Without a brace across the corner both members *may* bend and wrinkles are produced. The reason *may* was used in the previous sentence was that the amount a stick bends is determined by its dimensions, load and stiffness. One or both sticks may be stiff enough to resist the stress. It is amazing how little the sticks have to bend for a wrinkle to show up. For some appreciation of this take a wing and squeeze it from the leading edge to the trailing edge, and notice how soon the wrinkles show up.

So we know where we need to place one, but what guides its size? The size is a function of the members strength that needs bracing and the force applied to it. I don't have an equation for all situations, but the following experimental data and analysis of plans may be useful. I made three 2-inch squares of 1/16 square, 6 pound wood. One had gussets starting at 1/3 of the span (.66 inches) and running across the corner and down the vertical member the same distance. This was done in all 4 corners of the square. The second one was the same but the distance from the corner that the gusset started was 1/6 of the span, and the third was 1/12 of the span. The paper was Japanese tissue in all three cases. The frames were covered on both sides with the paper grain running in the same direction on both sides. It had been pre shrunk once before being applied to the frames.

After the frames were covered, but not doped, they were all exposed to a fine mist and allowed to dry. The sample with 1/12 the span had the most wrinkles. The sample with the braces at 1/6 the span was fine, no wrinkles, and the same for 1/3 the span. I have since looked at other structures and found that some times those with 1/6 the span had wrinkles. When I look at plans you see all kinds of spacing, but some of the builders who are frequent winners brace at about 1/4 the span.

That seems like a safe distance. Braces at 1/6 of the span may be a little risky. Even though all the wood strips in a structure are stripped from the same plank, they can vary a great deal in how stiff they are.

Since tissue may not pull equally hard on both members in a corner, it may be possible to have an angle other than 45 degrees for the bracing member. Joint angles other than 90 degrees, such as where the fin leading edge meets the bottom of the fin, may also require different treatment.

Frequently on plans the gusset is shown as a solid piece with the grain running at 45 degrees to the 90-degree corner members. I have tested a solid gusset versus just having a stick running across the inside of the corner. (Now I suppose we have another language problem — is this stick a gusset or a diagonal brace?) Any way I found the stick is as strong as the solid gusset and lighter. This stick does not need to be of the same cross section as the members forming the corner (the typical specification laid out on some plans). Instead of it being 1/16th square it could be 1/16th by 1/32nd and then it could be twice as long for the same weight. Thus giving more security. With the short distances typically involved, buckling due to compression is not an issue. For other reasons twisting of the corner brace is not an issue either.

I also investigated the merits of having a gusset with concave radiused corners by talking to a PhD civil engineer. His opinion was that a gusset should be a straight line

Hope this helps you to build stronger lighter models with fewer wrinkles. If any of you have additional data I'd be happy to hear about it. My email address is donmiller@olympus.net. My regular address is Don Miller, 835 Jackman, Port Townsend, WA 98358