THE GLIDING FEDERATION OF AUSTRALIA

AIRWORTHINESS ADVICE NOTICE

GFA/AN 69
Issue 3
23/6/1987
Sheet 1 of 15

TYPE AFFECTED: All sailplanes and powered sailplanes originally externally finished in "Vorgelat" gel coat.

SUBJECT: Gel coat failure, its removal, replacement and care.

PURPOSE: This A.N. has been assembled to provide guidelines for those members who are currently faced with the problem of failure of external gel coat, or who may face it in the future.

BACKGROUND: This A.N. was first issued in 1984, revised in 1986 and re-written in June 1987.

There are in excess of 270 sailplanes in service in Australia with "Vorgelat" gel coat exterior finish. Many of those sailplanes have already had their gel coat removed or partly removed and re-finished in any one of a number of materials.

This problem has three serious implications:

1. Substantial cost to rectify.
2. Substantial risk that the structure of the sailplane will be damaged during removal of the gel coat.
3. Long term deterioration of the FRP structure if rectification work is delayed, not done at all, or done incorrectly.

Since 1984 we have seen a number of sailplanes subject to gel coat removal which, because of the way they were done are now having to be re-done, some of them having had significant damage incurred to wing and tailplane skins.

It is anticipated that many sailplanes will be re-finished up to three times.

REFERENCES: The following publications are supportive material for this A.N.

1. AD 278
2. Section 2 of the GFA Inspectors Handbook.
3. Repair manual of each glider or powered sailplane under review.
4. GFA Technical reprints

THE GREAT MYTH

F.R.P. is not the "miracle", forget all about, non maintenance material many people expect it to be. We have learnt that FRP requires just as much care and attention as any other sailplane construction material.

GEL COAT....ITS HISTORY OF BREAKDOWN

Back in 1982 we provided the Materials Research Laboratories with gel coat samples, taken from sailplanes while being re-finished due to gel coat failure. The opinions M.R.L. provided assisted in the printing of AN 69. Issue 1, (21.11.1984).

AN 69 was written on the basis that we expected gel coat failure cracks would "transfer", causing cracking in the glass/epoxy layers under the gel coat. What was not known was how long it would be before we saw that cracking develop.

Late 1985 early 1986, two of our professional workshops found clear evidence of crack propagation from the bottom of the gel coat into and through the top skins of a Hornet wing, Mosquito wing and Cirrus 75 tailplane.

Samples were taken from the Hornet and Cirrus and sent to the DOA laboratory in Canberra for microscopic examination to try to establish the mechanism of this crack transfer.

It must be noted that at June 1987 the "cracking" seems restricted to the epoxy resin in the skins, the question being - how long can cracked gel coat be left before it will induce glass or carbon fibre breakdown?

This history is relevant - (Typical Hornet sailplane).

1. First flight 1976
2. First cracks 1978/79
3. Gel coat cracked right through 1981/1982.
4. First "etching" of epoxy/glass layers 1982/3.
5. Crack propogation completely through the <u>epoxy</u> in the epoxy/glass layers 1983/85
6. Crack propogation through the <u>glass</u> in the epoxy/glass layers 1985-???

Bluntly we are generally looking at potential structural damage, due to gel coat cracks, within 8 to 15 years from date of manufacture, if rectification action is not taken.

GEL COAT - FURTHER RESEARCH

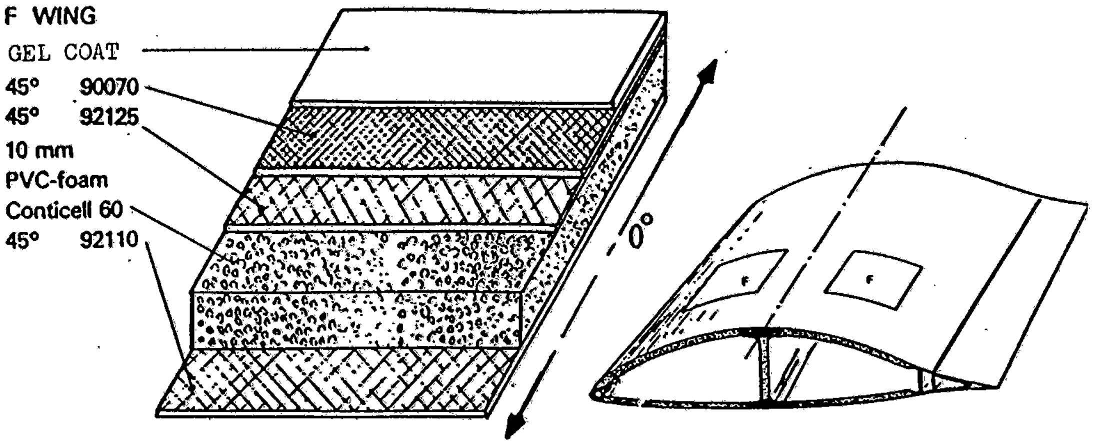
1987/1988 will see more research carried out to establish more clearly the mechanism of crack growth once it has transferred from the gel coat into the structural layers.

That research will clarify the question of the possibility of cracking slowly propagating into spar rovings and what effect that could have short and long term on strength and fatigue lives.

GEL COAT....UNDERSTANDING THE STRUCTURE..

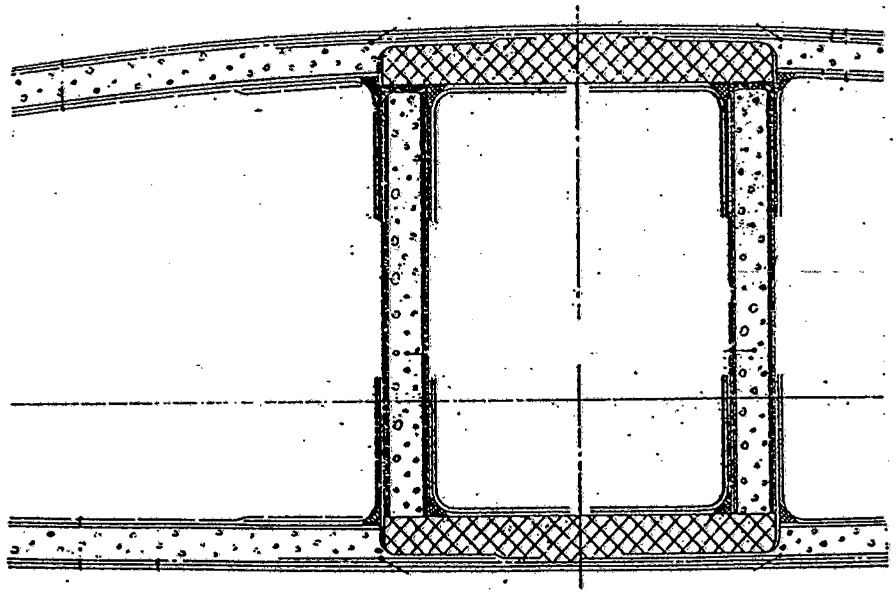
Before attempting to replace gel coat, the structure of the sailplane must be clearly understood, particularly wings, tailplanes and control surfaces, all of which have very thin structural skins.

This is a typical wing section.



BOX SPAR.

This Carbon Roving Box Spar extends out to the outer skin layer. The wing skins forward, over and rearward of the spar have extra layers of Glass or Carbon fabric for local load distribution and contour stability.



THREE THINGS MUST BE RECOGNISED:

(a) The glass/epoxy layer is very thin and quite flexible.

(b) The gel coat varies considerably in its thickness, and is very stiff.

(c) Unless a manufacturer says so there is no "sacrifical layer" on the outside of wing or tailplane shells.

GEL COAT ... TYPES OF FAILURE

It is important to understand that there are 3 types of gel coat failure, which fall into two categories.

"Breakdown" which is the collapse and failure of the gel coat and "strain failure" resulting from either gel coat stress and/or sailplane structural stress.

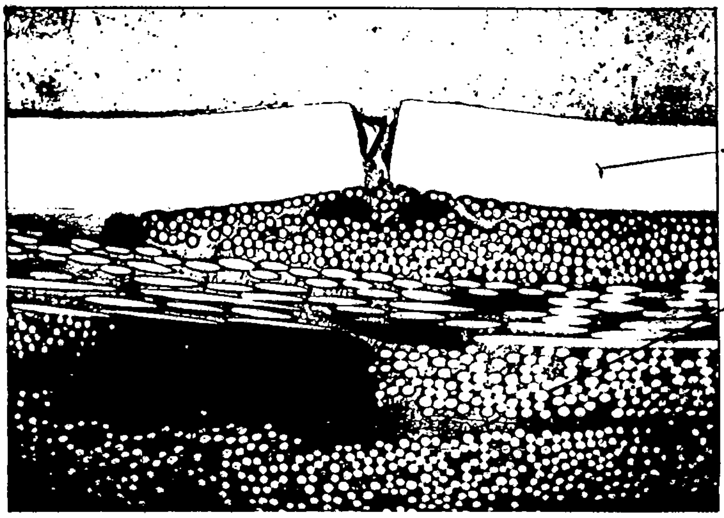
(1) GEL COAT BREAKDOWN

(a) **RAPID** fine crazing and cracking on the surface usually within several years of entering service, typical of Hornet, Mosquito, some LS series.

(b) **SLOWER**, similar crazing and cracking over longer periods of time typical of Cirrus, Nimbus, Janus, etc.

NOTE: Cases (a) and (b) exhibit two types of gel coat behaviour after cracking has started.

1. Where the gel coat has very high "surface tension", the gel coat will "curl up", such that it is rough to the touch and pieces can be picked out. This gel coat is not usually stuck firmly to the layer underneath.



2. Where surface tension is lower, the gel coat doesn't lift or curl and is stuck much more securely to the underlying layers. This gel coat seems to "transfer" its cracks into the underlying layers more readily.

(2) STRESS/STRAIN CRACKS

Strain cracks which are the results of structural stress causing the gel coat to fracture, the gel coat acting as a "tell tale" indicating structural distress.

(3) FILLER CRACKS

FILLER CRACKS which occur on the outside of the manufacturing joints.

GEL COAT ... WHICH ONE CRACKS?

Sailplanes originally finished in "Vorgelat" gel coat have suffered cracking and breakdown failure as outlined in (1)a and (1)b above.

Sailplanes originally finished in "SCHWABALAC" have not experienced that type of failure up to 1987. "Chalking" of the surface if not kept polished, is common. Strain failure and cracking along filled joint lines is common in both.

GEL COAT ... WHY DOES IT BREAKDOWN?

In the case of (1)a and (1)b above, there are some common factors, which vary relevant to the type of sailplane; whether it was manufactured in summer or winter; post purchase care; type of operations; exposure to moisture; exposure to ultra violet light; and others.

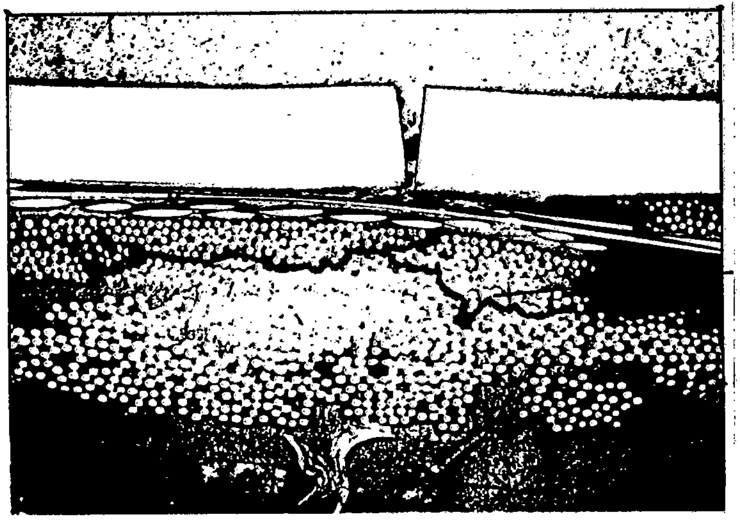
For (1)a and (1)b above the following is generally applicable:

(a) The gel coat manufacturer claims that "as formulated" and delivered to the sailplane manufacturer it should not crack. However it is recognised that during the period of manufacture of the sailplanes affected there were changes to gel coat formulation and some quality control problems.

The gel coat in question also has a short storage life.

(b) We understand that the sailplane manufacturer, as aids to production, may have used high levels of thinner and hardener, particularly in colder conditions.

This "modification" to the gel coat creates a material which is harder, more brittle and with a high level of "surface tension" after it has cured. It also has a significantly different coefficient of expansion compared to the epoxy/glass (or carbon) layers underneath.



150 MAGNIFICATION
Gel Coat Cracking has penetrated the glass/epoxy layer creating a delamination.

GEL COAT

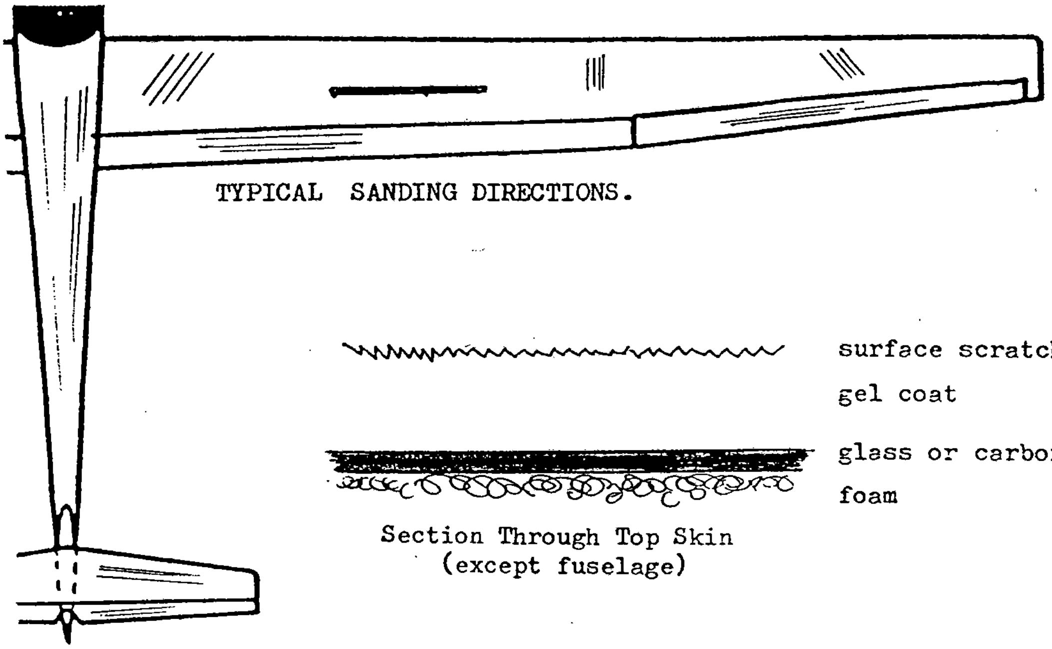
DELAMINATION

GLASS STRANDS

FOAM

(c) The sailplane manufacturers finish sanded the gel coat, particularly the wings, to achieve laminar surfaces, using up to 1200 grit paper.

Sanding the gel coat creates a scratched or notched surface, the same as marking a sheet of glass with a diamond; those notches acting as trigger points for cracks to start from. On wings, these fine scratches are chordwise/diagonal at 45 degrees, on the control surfaces, usually spanwise.



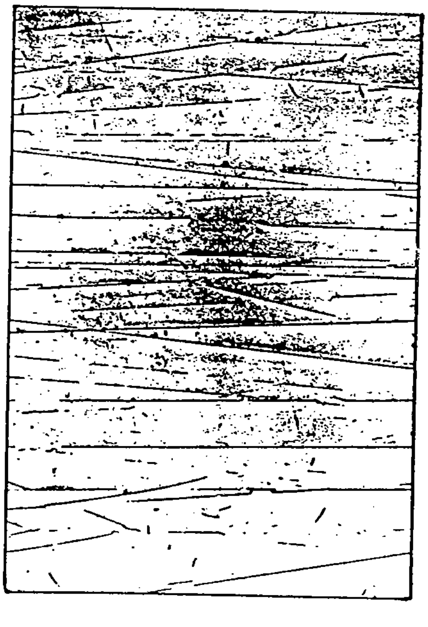
TYPICAL SANDING DIRECTIONS.

Section Through Top Skin
(except fuselage)

GEL COAT ... CRACK IDENTIFICATION

Unfortunately there has become a tendency to simply put all cracks into the same basket and not necessarily take the time to identify type and cause. **THIS CAN BE DANGEROUS.**

GEL COAT BREAKDOWN must be distinguished from Strain Failure because under strain failed gel coat there may well be damaged composite structure, likely to render the sailplane un-airworthy.



This illustration is typical gel coat breakdown, short random cracks.

By comparison Strain cracks are more defined, deeper and longer.

STRAIN/STRESS CRACKS

Strain cracks can be a very useful tool for the sailplane inspector. Likely places to find these cracks are:

Wing lower surfaces
Either end of divebrake boxes
Join of fuselage to fin
underside of tailplane.

Causes for strain cracks can be:

Flight overload
Ground impact
Ground induced vibration
Inadequate repairs
Thermal stress/strain.

WAVE FLYING

Climbing into below zero conditions can cause high stress in the gel coat due to contraction plus freezing of any trapped moisture. Rapid descent can generate a significant temperature difference between the gel coat and the underlying layers, again creating gel coat stress - an ideal basis for strain cracking through existing cracks initiated by gel coat failure.

This problem is well recognised by sailplane manufacturers.

FILLER CRACKS

Filler cracks occur on the outside of manufacturing joints, in particular along:

Wing leading edges
Fin leading edges
Tailplane leading edges
Top and bottom fuselage joints

The causes of filler cracks can be all of the reasons mentioned for Strain Failure combined with shrinkage of the epoxy/flock/micro balloon joining compound used in the joints.

GEL COAT ... CAN YOU STOP IT BREAKING DOWN?

(a) BEFORE IT STARTS

On a sailplane that has not yet started, or cracking is very fine and shallow:

(1) Sanding with very fine paper, across the original sanding marks removing the factory produced notches, followed by regular waxing has been shown to be effective in retarding possible cracking. This process repeated every soaring season with wax kept on the surface **ALL THE TIME.**

(2) Lightly sanding as in (1) and spraying with a lacquer or polyurathane paint system has been proposed for sometime and completed on some gliders. However it is not clear at the date of this issue that this is a realistic exercise, since some of those refinished sailplanes have started to shed paint due perhaps to **APPLICATION PROBLEMS.**

(3) Keep water away from the surfaces.

(4) Keep a good coat of silicone free polish on the surfaces at all times.

(b) AFTER IT HAS STARTED.

Once it has started the cracking will continue at the rate dictated by the many factors involved (fully variable) but some slowing of the process can be achieved by:

(1) Keep water away from all surfaces.
(2) Keep a good coat of silicone free wax on all surfaces at all times.
(3) Store dry, keep away from wet dollies, leaking trailers and wet hangar floors to be avoided.

NOTE!
For FRP sailplanes the use of wing covers has been questionable, since under some circumstances they can induce moisture onto the wing skins, in some cases causing actual condensation.

GEL COAT ... WHAT ABOUT SILICONE POLISH?

If a silicone based polish is regularly applied it will, in all probability, slow down crack growth by keeping moisture out.

Most silicones will" migrate" into the gel coat, and into the glass/epoxy layers underneath, contaminating the structure so much that any repair work needed later on may have difficulty in achieving proper bond.

During 1982, GFA asked each manufacturer their views on the use of silicone polish. All manufacturers except one said **NO** to the use of silicone; the lone manufacturer who said **YES, provided** silicone remover was used before attempting structural repairs.

Some new compounds using silicone do not contaminate and are being used in the automotive industry, without adverse effects during re-painting, etc.

So, **DON'T** use silicone, you don't have to.

GEL COAT ... CRACK GROWTH FACTORS.

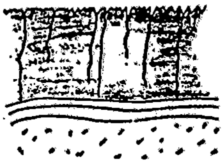
Irrespective of the initial cause of the gel coat cracking, all gel coat cracks can, given time:

(1) Travel right through the gel coat.

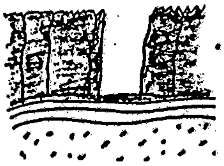
(2) Transfer into the epoxy in the first layer of epoxy and glass or carbon under the gel coat;

(3) Spread laterally, delaminating the skin layers.

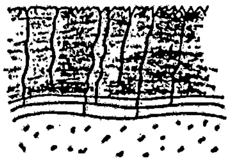
Initial surface crack propogated by the factors mentioned.



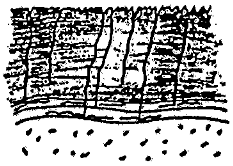
With time the cracks go right through to the top of the glass/epoxy matrix.



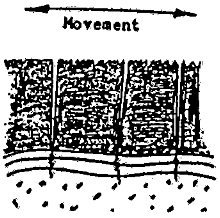
Moisture will cause separation of the gel coat from the matrix, to the extent that pieces will fall out.



Moisture at the bottom of a crack will "etch" the top of the glass epoxy matrix which will then allow, with time, cracks to grow into the matrix.



Once the cracks have reached the glass/epoxy, moisture can travel into and split the glass from the epoxy, causing total collapse of the structure. (Hornet rudders are a good example of this).



Expansion/contraction/movement of the gel coat can induce fatigue of the glass/epoxy layer immediately under the crack, even extending into the foam core. Moisture penetration helps this action.

(4) Travel completely through the skin layers of wings, tailplanes, fins, rudders, elevators, flaps and ailerons.

(5) Transfer into and through the foam layers of sandwich skins.

(6) Transfer from skin layers into spar caps.

(7) Cracks allow moisture penetration into structural material.

The time scale for crack travel and transfer is completely variable from one sailplane to another depending on each individual combination of factors.

The long term airworthiness implications that are relevant, (if rectification is not undertaken or left too long) are:-

(1) Loss of torsional stiffness in wing sections.
(2) Loss of strength or fatigue life in spar assemblies.

GEL COAT ... WHEN SHOULD IT BE REMOVED.

If you take into account all of the **FACTORS** in crack growth, and the long term influence it may have on the structure, it is clear that cracked gel coat should be removed before cracking reaches the underside of the gel coat.

This can be assessed by selecting heavily cracked areas, applying a dye trace and dry rubbing back, checking crack depth as material is removed. This is not conclusive since crack depth can be very shallow and very deep in adjacent areas. It is random.

GEL COAT ... WHAT CAN REPLACE IT?

The properties that a new external surface material should have, include:-

(1) Same level of ultra violet resistance as original gel coat.
(2) Water resistant
(3) Flexible
(4) Abrasian resistant
(5) Readily cut back and repaired
(6) No special skills to apply.
(7) Ideally, to act like gel coat does as a "tell tale" in that surface cracks will appear after high structural stresses have been experienced, before structural failure. (A significant aid to inspectors).

NOTE: In 1985 we saw fractured glass under a polyurathane coating which had not broken or cracked due to its high flexibility.

CHOICES:

Every chemical company representative becomes an "expert" on what paint will do the replacement job best, so to specify any particular paint system is difficult.

In 1987 we do know that some paint systems thought highly of two or three years ago haven't performed for widely different reasons. Other systems are still to prove themselves.

The following list is the top 4, with no guarantees -

1. SCHWABALLAC GEL COAT (so far trouble free)
2. AUSTRALIAN "FERRO" GEL COAT (so far trouble free)
3. URACRYL ... by Spartan (reasonable performance)
4. FORMINEX POLYURATHANE (reasonable performance)

GFA RECOMMENDATION:- GFA STRONGLY RECOMMENDS ONLY REPLACING GEL COAT WITH GEL COAT.

NOTE! IRRESPECTIVE OF CHOICE OF FINISH, THE CORRECT METHOD OF APPLICATION IS THE BIGGEST DETERMINING FACTOR IN HOW WELL THE MATERIAL PERFORMS IN SERVICE.

APPLICATION CONSIDERATIONS:

(1) After the gel coat is removed, an undercoat must be applied, if gel coat is not being used to re-finish.

(2) The undercoat must be the right formulation for the finish coat, particularly if you want to use polyurathanes as they in themselves are not moisture resistant.

(3) Excessive humidity must be avoided while applying the final finish.

(4) Most finishes are a health hazard, so ventilation and adequate breathing equipment is of prime importance.

NOTE!

YOU MUST BE VERY SURE THAT THE STRUCTURE HAS NOT ABSORBED MOISTURE AFTER THE GEL COAT HAS BEEN REMOVED. IF THERE IS ANY DOUBT, BAKE THE STRUCTURE LONG ENOUGH TO DRY OUT EXCESS MOISTURE.(DO NOT EXCEED 54 degrees C.)

SURFACING AND CONTOURING

The following items are taken from the Inspectors Handbook, illustrating a sanding method that can develop a continuous contour and a gauge that can check deviation of the general shape from a average contour.

How To Build A Surface Wave Gauge in One Hour

I have received a number of inquiries about the construction of the wing-surface waviness gauge that I use to measure the wings of sailplanes that DGA flight tests. The accompanying sketch may be used as a guide by those wishing to construct a similar unit.

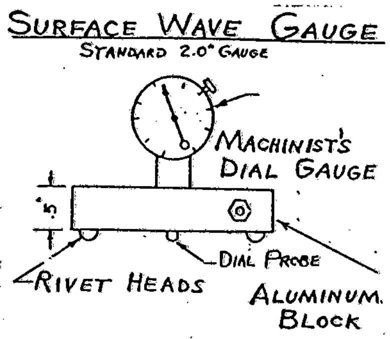
It can be easily made in about an hour or so if one has a small block of aluminum, a machinist's dial, three round-head rivets, and a #6 screw and nut. The machinist's dial gauge need not be highly precise nor expensive because an accuracy of more than about .0005 inches of measurement is not needed for normal wing surface measurements.

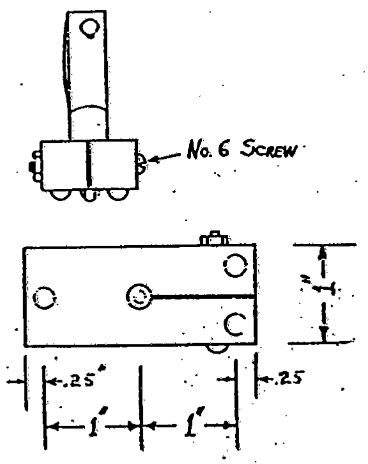
This gauge is designated as a 2.0-inch gauge because the block support rivet heads (can be wheels) are separated lengthwise by that distance, and the dial probe is located midway between the supports.

I generally use the gauge by holding it against the wing's surface and running it in the chordwise direction. A perfect surface should show a continuous and smooth rotation of the dial as it passes from near the leading edge to the trailing edge. A "wave" is indicated by back-and-forth motions of the dial, where it should be showing a steady sweep. The wave height designation that I record is the peak-to-peak value shown by the dial; that is the maximum reading minus the minimum dial reading as the gauge traverses the wave area.

With a little practice one can quickly locate high and low areas on the airfoil surface. I generally sand off the high areas, where possible, and fill the low areas with an epoxy resin and microballoon mixture. Featherfill or similar free-sanding surfacing materials will do well for filling also. Avoid brittle and low-adhesion materials such as lacquer primer surfacers, except for small and shallow filling, because they will crack and peel with age and wing flexing.

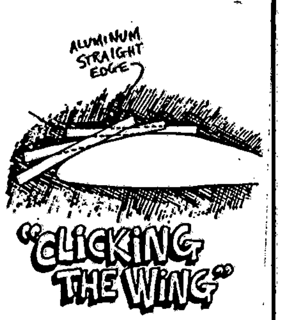
DICK JOHNSON
Dallas, Texas

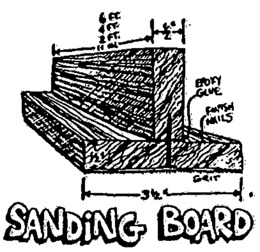


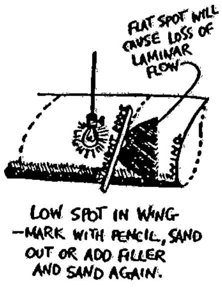


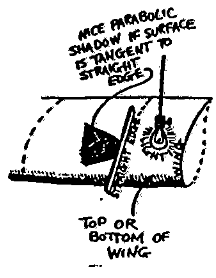
"CLICKING" THE WING;

These illustrations show another method of checking the wing surface for smoothness. Sanding boards of various lengths allow the surface to be roughed down to approximate shape, final sanding done with an aluminium or steel straight edge which will make a slight clicking sound as it rocks over a flat spot, the light also throws a shadow that indicates a flat spot.









GEL COAT ... BEFORE IT IS REMOVED.

Before taking any action at all there is some homework you should do:-

(1) Read AD 278 and recognise the procedure required to make sure, after all the work is done, that your glider is not only sound, but others know it is sound.

(2) Empty weight of the glider and the weight of each wing panel should be determined.

(3) Balance and weight of all control surfaces should be established.

(4) The wing frequency should be recorded.

This data will allow you to fully establish what influence the gel coat replacement has had on the finished glider.

(5) Decide how you are going to ensure that the finished wing profile is either:-

(a) The same as it was before you started

or

(b) Matching the section co-ordinates the designer aimed at originally.

It must be recognised that wing sections, particularly laminar flow, can be very sensitive to changes of contour, affecting performance, stall speed and in the extreme, stability.

WE HAVE SEEN A GRP GLIDER DROP FROM 1:35 TO 1:27 AFTER RE-FINISHING, SO WE MUST BE CAREFUL!

(6) FLIGHT TESTING

It would be considered good housekeeping to conduct test flight evaluation both before and after re-finishing.

The test flying should note:-

(a) Test flight gross weight and c.g. location.

(b) I.A.S. stall speed, in the full range of configurations available.

(c) Wing drop, or roll tendency, from stall to at least max manoeuvre speed.

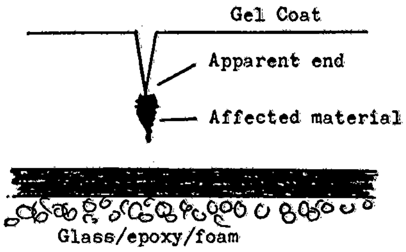
Comparison before and after re-finishing could highlight any deficiencies introduced by the re-finishing process.

Obviously full performance testing would be very difficult, but where a competitive glider such as a Nimbus 3 (for instance) is concerned, some comparative performance evaluation may be very important. A drop from 55:1 to 50:1 may not be readily apparent.

GEL COAT ... REMOVING IT.

Before starting to remove the gel coat, let's get to understand what a crack is.

The sketch shows a crack part way through a gel coat layer. There will be a "Visual End" to the crack, but there will be "Crack Affected" material past the end of the crack. If that is left on the structure and surfaced over, there is every possibility that cracking will restart possibly spreading both ways.



This means that to give the best guarantee of producing a good long term result, **ALL OF THE GEL COAT** must be removed.

That statement must be tempered by some common sense but keeping the principle of complete removal firmly in mind.

(a) USE OF DYE TRACE.

A dye trace of some type is essential if the paths of cracks, particularly those transferring to other layers are to be followed properly.

(b) BY HAND.

A rubbing block, patience and care, starting with coarse paper, grading back to finer paper as the structural layers are approached, will see the job done in many hundreds of man hours, **BUT WITH LEAST RISK OF SURFACE DAMAGE!**

(c) BY MACHINE

Please, only if you have the skill. It is a lot quicker, but the risk of damage to the structural layers under the gel coat is very real.

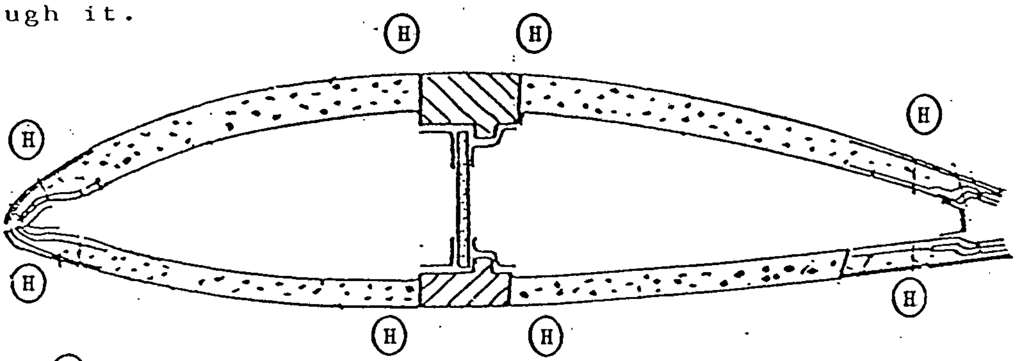
OVERHEATING will occur if too high a speed is used or the machine not kept moving, causing the glass epoxy layer to separate from the foam core.

NOTE! DO NOT USE WATER AS AN AID TO RUBBING BACK. IT WILL SOAK INTO THE STRUCTURE EASILY AND TAKE A LONG TIME TO DRY OUT, IF EVER.

(d) MAIN POINTS OF LIKELY DAMAGE

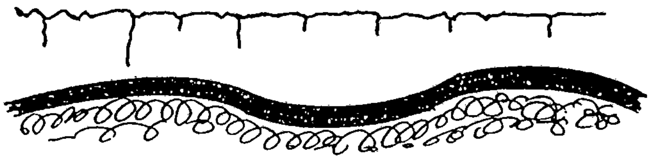
Assembly details of the **INTERNAL** structure will cause "ridges" and "hard" spots that will be rubbed through more than adjacent areas unless you are careful. Obviously this will vary from one type of glider to another.

Let's look at our cross section and take several "slices" through it.

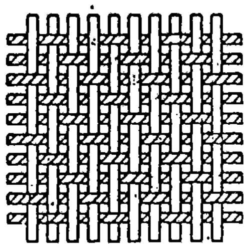


(H) Typical "hard" points which can be easily sanded through

Cutting through the glass/epoxy layer will weaken the structure by lowering its stiffness. The more damage created, the more the structure will be affected, Loss of stiffness will affect fatigue life and flutter.



Older gliders and repaired areas can have large variation in gel coat thickness due to the glass or carbon fabric not being laid down flat.



Typical "TWILL WEAVE" fabric illustrating how the cloth is structured. The strands are bundles of fine glass or carbon threads, flattened out.

Sanding off a ¼ of the thicness as shown below actually removes a substantial amount of the cloth.

sand line.

IF YOU CAN SEE, VISUALLY, SANDING DAMAGE TO A CLOTH LAYER, THAT LAYER IS MOST LIKELY SEVERELY DAMAGED.

(e) <u>REPAIRS</u>

Skin or sandwich repairs must be carried out if:-

(1) Cracks are found transferred to structural layers. These areas to be removed and replaced.

(2) Damage due to the sanding process must be repaired.

(3) Some original structure has been found to be of such poor quality ("dry", etc) that repairs have been necessary.

(4) If the number of minor local repairs is high, it is better to sheath the surface with one new layer of glass fabric identical to the existing outside layer, laid with the weave in the same direction.

Repairs and repairers must comply with AD 278 and Section 50-5-2 of the M.O.S.P.

CONCLUSION:

These are the key facts from this A.N.

1. Keep water away from the sailplane. Don't even wash it with water.

2. No silicone polish.

3. Keep a good wax on the surface, filling the cracks as completely as possible.

4. **WHEN** refinishing is to be undertaken **BECAUSE** of cracked gel coat, **ALL** of the gel coat **MUST COME OFF.** If any gel coat is left on, the remains will eventually cause cracking through the structural layers.

5. Do not "wet sand" when removing gel coat.

6. The gliders so far that have been re-finished, but only partially sanded back, (cracked gel coat left on), and there are a lot of them, painted with nice tough flexible polyurathanes and acrylics **will probably** continue to crack under that new paint job.

7. Damage to the glass/epoxy structure during removal must be avoided at all costs.

8. An independent inspection of the epoxy/glass surface must be carried out to AD 278 before the new finish is applied.

9. Replace the gel coat with preferably Schwaballac gel coat or local Australian gel coat, to provide easier profiling and telltale cracking under structural stress.

10. Attention to the profile of the wing section should be given priority.

11. Control surfaces must be re-mass balanced to maker's specifications.

12. Sailplane must be weighed on completion and re-placarded.

13. Wing frequency to be measured and recorded in the logbook.

14. Logbook entry noting AD 278 compliance to be made.