Sonex 1153 - VG Test Program

DISCLAIMER - CONDUCTED WITH ONE EXPERIMENTAL AIRCRAFT IN ONE VERY SPECIFIC AND CONTROLLED CIRCUMSTANCE TO TEST ONE PARAMETER. YOU SHOULD NOT RELY ON THIS DATA OR INFER OR CONCLUDE ANYTHING FROM IT TO APPLY TO YOUR AIRCRAFT.

Introduction:

Vortex generators are small components deployed on the wings and stabilizers surfaces. They modify the flow around the surfaces affecting boundary layer. Properly arranged, improve the performance and controllability of the aircraft, particularly at low flight speeds, climb, and high angles of attack.

Most sources suggest VG's should be installed where boundary flow/laminar separation takes place on a wing in slow flight and that this is generally between 7% and 9% aft of the leading edge along the chordline of the wing.

Most manufacturers seem to all promise the same - improved lift, climb, slow speed handling, and claim no downsides. None seem to offer any test data to back up their claims! Something for nothing - seems hard to believe….

This program was to simply determine if the VG's do improve boundary flow in the area of a stall in some gross and distinctly observable manner. It did not attempt to observe "finer" aspects to determine if the installation angles and spacing of the VG's was optimal.

Aims:

To determine if Vortex Generators improve the adherence of air to the standard Sonex Wing at low speeds.

To determine what changes in handling characteristics a set of VG's causes.

Method:

The wings were wool tufted and flown and photographed at differing airspeeds in order to observe the airflow across the wing and to attempt to determine the actual separation point for the Sonex wing at low airspeeds associated with boundary separation.

3" acrylic wool tufts in a contrasting color to the metal wings were taped at intervals of the wing ribs x 4 rivets fore and aft. 3 rows of additional intermediate tufts were placed in between tufts in the area of the leading edge where the wings are flush riveted, to just behind the skin where the rivets transition to proud rivets. The assumption being that once fitted with VG's - this would be the area of most interest. A total of 96 tufts were applied to each wing for a total of 192 tufts. Control surfaces and the horizontal stab were not tufted.

The aircraft was flown and photographed at various airspeeds to determine an airflow separation point.

Some "quick" VG's were made up from 1/2" angle x 1/16" thick x 2" length aluminum stock and taped to the wings at 90mm intervals with alternating 4 degree angles at 8% MAC from the leading edge. VG's were installed from wing root to the outer edge of the flaps. For safety - no VG's were placed ahead of the ailerons. This was in order to ensure aileron authority during testing.

The test flight was repeated and wool tufts observed to determine if the VG's had made any difference to the separation point.

In as much as it was possible. All aspects of aircraft, flying and "numbers" were kept the same with the only difference being the fitting of the VG's and observation of differences caused by them. For example issues such as pitot static calibration errors at low airspeeds and high angles of attack exist and numbers observed may be "wrong". But broadly the assumption was made that by keeping everything else the same - these errors were "equally wrong" for all observed states.

Actual Flights:

Aircraft - Sonex Serial 1153

Engine - Aerovee 2.1

Modifications from otherwise standard design - Aircraft was flown without wheelpants over tires but with gear fairings over gear legs.

There is a NACA airscoop under the chin of the cowl that provides outside blast air to the air filter under the cowl.

A series of three flights were performed totaling two hours of test flying time. (Local advancing and retreating coastal fog requiring a precautionary landing at one point to maintain VFR and the aircraft had to be landed to fit the VG's!)

Weather conditions prevailing were 27C at MSL, with a light south to south east airflow holding a fog bank along the coast line. Air in the test area and above the edge of the fog back was smooth without turbulence.

Aircraft was flown at 2,500ft MSL +/- 100ft in a DA of +500ft. So the aircraft was flown at ~3,000ft DA

Aircraft was flown with one person and full fuel less fuel burned during flights. In practice this meant aircraft weight was between 960lb reducing to 940lb during testing.

Aircraft was flown at a series of decreasing indicated airspeeds. Power setting used was sufficient to maintain fixed altitude while flying each airspeed. At low airspeeds (less than 40KIAS) power was not sufficient to allow maintenance of altitude at high pitch angles without engine overheating due to low airflow in the cowl. Power was reduced and altitude was allowed to decay while maintaining pitch angle and airspeed when this occurred. Generally, at 40 KIAS or less.

The aircraft was flown inside the FAA issued Phase 1 test Operational Limits to the east of KUUU - Newport State Airport over the area of Little Compton.

Legs were flown back and forth in the test area till a total of 4 "runs" were constructed:

Run 1 - Clean wing

Run 2 - Flaps 20 wing

Run 3 - Clean wing fitted with VG's

Run 4 - Flaps 20 wing fitted with VG's

On each "run" the aircraft was flown in increments where airspeed was reduced from 70 knots to 20 knots (+/- 1 knot) INDICATED airspeed in 10 knots increments. Around the area of the stall - additional increments were attempted at 35 and 25 knots. An attempt was also made to identify the lowest airspeed at which the aircraft could be controlled in each configuration.

During all observations the aircraft was flown level and coordinated by visual flight rules and observation of the Attitude Indicator and "ball" generated in the MGL Enigma EFIS system from a Magnetometer / AHRS.

No attempt was made to measure fuel consumption differences.

Observations:

1. No "gross" airflow separation improvements were easily observed between a clean wing and a wing fitted with VG's. This is not to say improvements were not there. At 30-40 KIAS it does seem that VG's keep the air adhered to the area of the wing roots better. Unfortunately Run 3's 40 KIAS video was not properly recorded - but the Run 3 - 35 KIAS and Run 4 - 30 KIAS video was and the air seems better attached to the wing in it compared to 40 KIAS in Run 1 without the VG's. But further test runs and more photography would be required to elicit any "finer" point.

2. During flights from the airport to the test area. With VG's installed there was a loss of 6-7 knots indicated airspeed at normal cruise power settings compared to previously measured "book" settings for this Power Setting / Density Altitude.

3. At airspeeds of 21 KIAS - stick and rudder held to maintain the attitude with no inputs - a level, coordinated, flaps extended wing - stalled and recovered in a gently snatching manner with fore and aft pitching observed. There was no tendency to drop a wing.

Fitted with VG's and held in the same attitude the indicated airspeed could be reduced to 17-18 KIAS. The plane no longer pitched back and forth gently but sat steadily in the attitude. However, when the stall break did occur - the plane dropped a wing significantly. Left and right wing drops were observed with the ball centered just prior to the drop.

4. VSI sink rate with the aircraft in extreme slow flight "stalled" but stable wings level:

- Flaps 20, NO VG's 20 KIAS. VSI minus ~400fpm
- Flaps 20, WITH VG's, 18 KIAS. VSI minus ~ 200fpm

5. During cruise flight the aircraft felt more stable in the roll axis when fitted with VG's. But it also felt "heavier" and less "nimble". (This is subjective with no "measurement" but it was absolutely a different feeling aircraft)

Discussion:

1. I am well aware this is an extremely small data set and that drawing conclusions without repetition of test flight results are less than wise. None the less I was able to observe clear "trends" that leads me to believe that VG's make a MEASURABLE difference to the aircraft handling and that further study would be of merit for those who are interested.

2. It was interesting to observe how well the wing "flew". The flush riveted leading edge were seen to maintain airflow at virtually all flight regimes - even into deep stalls where the plane was in a high angle of attack and the whole of the aft surface of the wing had airflow separation.

A surprise for this "Hershey Bar" flat wing was how the air separated and the wing stalled in the wing root first and the wingtips maintained airflow and aileron authority without the help of twist or washout in the wing. I've always felt the wing was very "honest" and gave you plenty of warning in the seat of your pants that it was going to stall. Video now confirms the stall in the aft wing root, transmitting that buffet to the seat of your pants while the rest of the wing keeps flying.

At the end of the video sequence there are a couple of shots during wing drop stalls of the disturbed air immediately reattaching as soon as the angle of attack is reduced. Almost instantly with the help of small firm stick pushes.

3. The reduced cruise speed could be caused for a number of reasons. A number of sources suggest that VG placement is a balance between improving airflow and the increase in drag caused by the VG's. VG's at 7% MAC are supposed to improve airflow better but at the price of greater drag. VG's at 9% MAC have less drag but are less effective at maintaining airflow. In the test I split the difference and put my VG's at 8% MAC. This also matched the installation recommendations from the STOLSPEED brand of VG's for LSA's. My VG's were also quite large and will have contributed to the drag. This was an exercise on trying to observe their effect. Not in VG design. Though interestingly one source suggested that they had "tried them all" and that they thought that at the low airspeeds we fly - the actual design made little difference.

Finally, the method of attachment with tape give only rough blending of the angle aluminum into the curve of the wing will have added drag.

But a 6% loss of cruise speed is significant. One has to wonder if even well made, blended installations have some effect on the cruise speed and that manufacturers' claims that there is "no loss of performance" are actually down in the 2% or less range - but is still there.

4. There is no doubt that even with my "lash up" set up - low speed handling in the stall regime was improved. Even if the wool tufts were not showing much to the eye. The plane was more stable in roll. Stall pitching was eliminated and the indicated airspeed that the stall break and pitch over occurred at was reduced from 21 KIAS to ~17-18 KIAS. However, I do have a concern that when the stall did occur - the plane dropped a wing more aggressively with VG's fitted, compared to without. I'm sure a function of the fact the wing was even slower than before. But of mild concern if you are hoping the VG's will provide more control at low speed. Possibly they do - right up till they don't and then control is lost in a more dramatic fashion.

When observing slow flight (and it is visible in the video) - at very slow flight around of < 25 KIAS - there is some significant left down aileron deflection to keep the plane level (the ball WAS centered). From past observation this is because the pilot is sitting left side. I know the plane needs some lateral trim to fly level with that load on one side and I have a small and light bungee I apply to the stick when the plane is flown solo to keep her level at cruise speeds. I remove it when the plane is flown two up. So - fly slower with less airspeed and it's going to need more aileron to keep the left wing picked up. This creates a situation where the effective angle of attack of the left wing tip is higher than the right wing tip. I would expect the left wing tip to stall first every time and for the aircraft to drop left wing. In practice I did NOT find this to be so. The plane dropped right and left wings just about equally. The only thing I can think might account for this is the "P" factor and right torque roll from the left turning propeller cancelling out the left aileron's tendency to stall the left wing first.

5. The addition of VG's definitely made the aircraft feel more stable. With VG's fitted I felt the aircraft MIGHT have broken ground better and in a more stable manner on the takeoff (but I wasn't testing that and it just might have been the wind was straight down the runway for a change during the tests!). It absolutely felt more stable in the roll axis and during the flights to and from the test area - the plane felt capable of more "hands off" with the VG's installed. But I was pretty sure this was at a cost of some of the nimbleness I love about the plane. She suddenly felt like a Piper Cherokee. Not a Sonex. More refined VG's might have a less pronounced effect.

Just to confirm this feeling - at the end of the airspeed test runs an additional test was performed with a series of full deflection aileron rolls using an entry of 125KIAS and 3 G pulls before full aileron deflection. From video observation compared to other flights in the past - I estimate the roll rate has gone from 90 degrees per second to something around 70 degrees per second with the VG's fitted. The aircraft still rolled safely and in some respects felt more like she was "on rails" through the roll. But she easily spent longer in the roll.

5. A limitation for this test was the lack of installed cameras for observation that were truly gimballed to vertical so angle of attack could be measured. I was trying to hold the camera "level" to horizon - and you can clearly see the trend - just don't try and measure it! I was trying to fly the plane accurately while making observations. I have discounted a lot of video because the plane was not in a stable airspeed or attitude. Used the stuff where it was stabilized on airspeed and altitude to make measurements. In this way I was able to find coarse measurement effects and record them.

If I was pursuing a VG program - I would fit left and right cameras for simultaneous observation, coupled to a camera observing the instrumentation to be sure what I was seeing absolutely correlated to the airspeeds and accurate flying. I would also experiment with moving the VG's forward and back along the MAC as well as experiment with different actual shapes of VG's.

Conclusions:

The installation of VG's does make MEASURBLE differences in the handling of THIS aircraft.

Identified differences include:

- A more stable aircraft in roll / Slower roll rate

- More stable slow flight handling in pitch (to a point)

- Poorer cruise airspeed (and so by extrapolation - poorer fuel economy)

- At high angles of attack with VG's fitted - at equal indicated airspeeds the aircraft sink rate was lower than without them fitted. This could correlate to the wing generating more lift.

Other possible characteristics possibly observed but not measured

- Improved lift at takeoff.

Finally

One of my principal missions for this plane is some gentleman's positive G acro - and if the VG's are going to interfere with that by slowing the roll rate - they are not staying on! But the tufts might well say on a little longer while I watch airflow during further acro and spin testing!

I found enough to tell me that I believe VG's “work” to a degree that manufacturers claim – but they are not for me.

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