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WHITE PAPER

Glasair III, Nose Gear Drag Link
Part Number: G3-DL5

The G3-DL5 Drag Link is an experimental, nose gear drag link designed as an alternative replacement to the Glasair-III factory kit supplied aluminum part.

PART HISTORY
The Glasair-III experimental aircraft homebuilt was introduced in the mid 1980s.

The original factory designed nose gear drag link and over-center down lock mechanism consists of a set of tubular steel drag braces and two aluminum drag links containing a machined over-center, down lock limit tab. The original design relied almost exclusively on system hydraulic pressure to keep the nose gear over center lock mechanism engaged during landing and taxiing.

If landing gear system hydraulic pressure was reduced or lost, landing on rough terrain, or experiencing a nose gear shimmy, the over-center geometry and mechanical advantage was occasionally insufficient to keep the over center mechanism from vibrating beyond the over-center point.

In August 1991, after several nose gear collapses, Glasair issued an urgent **Mandatory Service Bulletin (MSB) #103** requiring all Glasair IIIs ready for taxi testing, or builds already flying, to immediately install factory supplied nose gear over-center down lock springs.

When installed, the new down lock springs provided a continuous downward force on the drag link and drag brace driving both parts solidly against the over-center down lock tab on the drag link, even with reduced hydraulic pressure.

MSB 103 stated, “Since we are still in the process of researching the best solution to this problem, the modification described here could be just a temporary fix.” This temporary fix was never modified and the springs modification became the accepted solution to the collapsing nose gear issue.

MORE COLLAPSED NOSE GEAR
After researching several nose gear collapses since the introduction of MSB 103 it was discovered that the factory aluminum drag link’s over-center tab had, in each case, been the primary point of failure which resulted in the nose gear collapsing. In each case the aluminum drag brace tab failed without first causing structural deformation in any other parts of the nose gear mechanism defining it as the weakest link in the system.

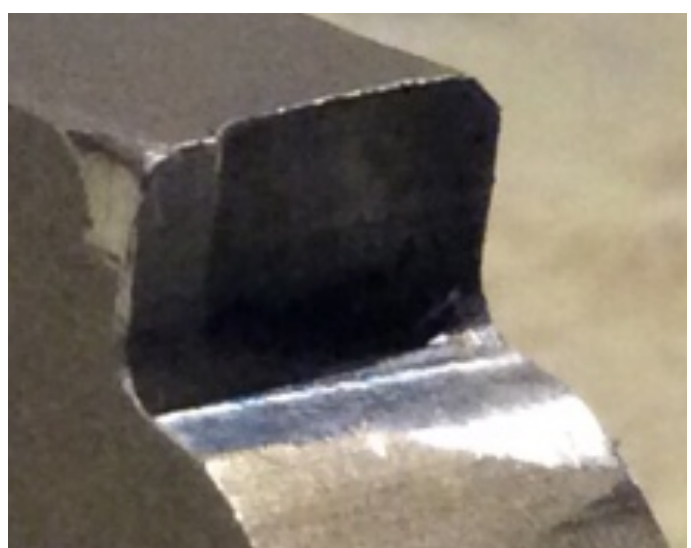
Nose gear collapse due to hard landing resulting in failure of aluminum nose gear drag link down-lock tab

During a rebuild of our test aircraft we found the drag link down-lock over-center tab deformation resulted in the down-lock geometry being 110% out of tolerance. Subsequent measurement of other Glasair III aircraft found 10 out of 11 other Glasair III's nose gear measured were out of tolerance, some by as much as 350% with one exhibiting impending failure cracks at the base of the over-center tab. Of the aircraft reviewed, there was a high degree of correlation between aircraft total time and the level of tolerance exceedance, a finding indicative of a progressive deformation within the nose gear system.

Extensive testing, evaluation of component shear limits, use of force transducers, and high speed camera footage indicated that the 1991 MSB#103 installed down lock springs were creating a new version of the problem they were designed to prevent.

FORCE DYNAMICS DURING GEAR EXTENSION

During the last 4" of nose gear extension, as the over center mechanism passes through the equilibrium point into an over center geometry, the down lock springs, which together exhibit a force in excess of 155 lbs, on the linkages (and aided by hydraulic down pressure), accelerate the drag brace and drag link into the aluminum, over-center down-lock tab.



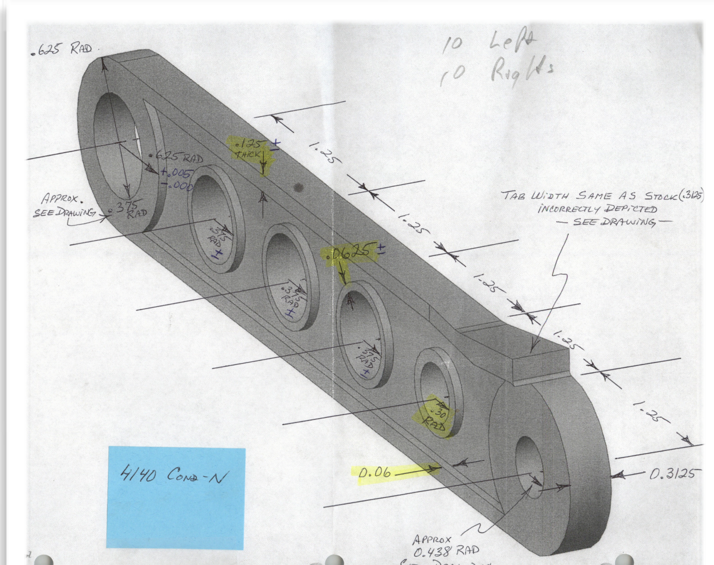
Closeup of aluminum down-lock tab plastic deformation and mushrooming

During several extension tests the pivot linkage immediately below the down lock tab reached a downward velocity in excess of 22 ft/sec just as the steel face on the drag brace made contact with the aluminum over-center tab. Calculations indicate the shear forces on the aluminum over-center tab during this high speed contact were within 20% of the ultimate shear values for the drag link's 7075-T6 aluminum.
These excessively high loads were consistently confirmed by evidence of mushrooming, plastic deformation, and cracks found at the base of

the aluminum down-lock tabs on both the left and right drag links on multiple Glasair IIIs.

Mushrooming of the tab, evident on every drag link we inspected, and strain hardening of the tab during the plastic deformation event results in increased tab contact area with the steel drag brace and improved force distribution into the steel frame. We believe these factors are both, in part, responsible for keeping more of these tabs from failing.

Consultations with a former Boeing PhD metallurgist confirmed that 7075-T6 aluminum supplied with the kit is a metal optimized for use in thin section aluminum. Use of 7075-T6 in parts approaching 1/4" or thicker (as in the factory drag link) should be avoided due to a tendency for "surface corrosion cracking." Additionally, the limited surface area available for the down lock limit tab to absorb the inertia inherent in the nose gear mechanism as it reaches the down lock limit, makes all aluminum types unsuitable to absorb these impulse, point loads, and shear forces with the factory defined springs installed.

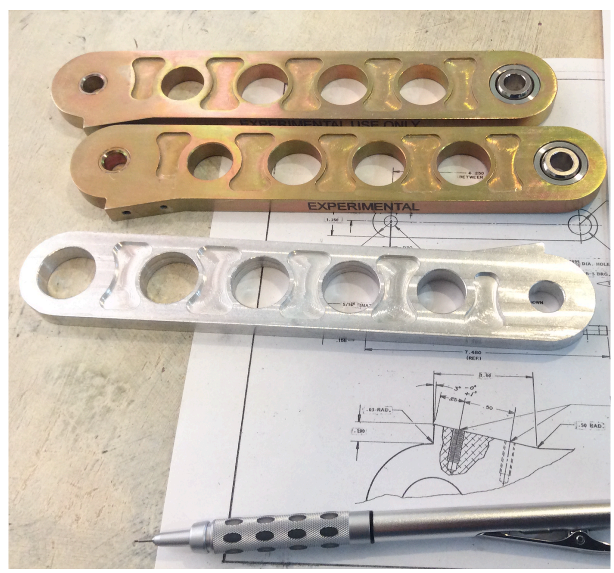


One of many prototype designs used in testing strength, failure modes, clearance requirements, and weight reduction

Our findings indicate that the down lock springs introduced with MSB #103, although aiding in preventing gear collapse during hydraulic pressure loss, have been instrumental in subjecting the existing aluminum drag link down lock tab to forces they were never designed to absorb.

DRAG BRACE DEVELOPMENT DECISION

Over the past four years Hansen Aerospace has been developing an external power supply system that will redefine how aircraft are supplied with and utilize ground power. Our Glasair III was purchased as a flying testbed and technology demonstrator for this "X-ternal Power" system. However, we were uncomfortable with the design, function, and strength of the nose landing gear system on an airplane that would ultimately represent five years of development work and showcase our new system.



Consequently, eight months of design, testing, and significant resources were allocated to the development and manufacturing of this nose gear drag link. From the onset we felt this redesign would strengthen one of the weakest links in the entire aircraft system and result in added value of an already exceptional aircraft.

FLIGHT TESTING

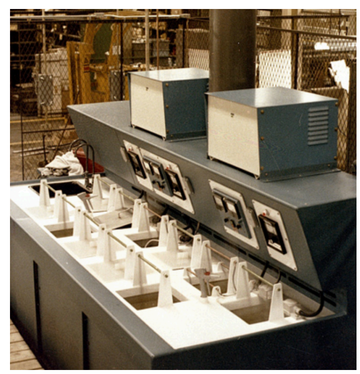
As of July 2017 our redesigned steel drag link has undergone four months of flight testing on multiple Glasair IIIs with over 100 cumulative landings. In June 2017 our test aircraft was flown in the Reno Air Race PRS race qualification program encompassing 17 landings, most of which exceeded the maximum demonstrated crosswind limit for the airplane and landing speeds at the nose tire 100 mph design speed limit, all without incident. Pilots flying the new drag link report the nose gear comes down firmly during extension and steering feels solid with less play during taxi compared to the previously installed aluminum drag link.

MATERIAL SELECTION
In this application, and from a strength perspective, steel and titanium become the only viable alternatives to aluminum without considerable redesign of the landing gear structure and mechanism. When prohibitive titanium machining costs are considered steel becomes the only viable alternative.

Steel alloys were considered based on strength (especially shear), toughness, atmospheric corrosion resistance, machinability, and wear resistance. 4140 alloy steel, Condition-N, was ultimately selected because it provided the best combination of material properties required. 4140 is extensively used in landing gear, spindles, missile rocket motor thrust braces, and other aerospace applications requiring very high strength.

HEAT TREATING
The 4140 steel utilized in the production of these steel drag links are normalized. Normalizing is defined as heating a steel to a temperature above the ferrite to austenite transformation range, approximately 1600 F (a bright orange-yellow) then cooling in air. In essence, normalizing is a technique used to provide uniformity in grain size and composition throughout an alloy providing increased strength.

CNC MILLING THE FINAL FORM
Heat treating is commonly performed on finished parts. However, heat treating can, in some cases, cause small distortions in longer and thinner parts. Because clearance values on both sides of the installed drag link are small during extension and retraction any distortion along the part's longitudinal axis were unacceptable. For this reason, individual, oversized, brick shaped steel billets were heat treated (normalized) in their entirety. Only after these billets had cooled for 72 hrs was the drag link's form CNC milled out of the billet's core to ensure the finished part remains perfectly square and true.



CAD PLATING
Once CNC machined to its final from the part is hot cadmium plated twice to increase molecular penetration depth and inhibit corrosion, even if scratched.

COMPONENT PARTS
The factory produced aluminum drag link contains a steel bushing below the down lock tab (forward end) and a spherical bearing on the aft end where it attaches to the drag brace. High spherical bearing loads (towing with a tug being a major culprit) combined with a coefficient of expansion for aluminum twice that of steel, has caused many of the pressed-in spherical bearings within the drag link to float under load. During landing and taxiing, this bearing undergoes highly cyclical loads causing increased wear between the floating steel bearing and its aluminum race. This bearing float results in higher loads within the aluminum link under and around the bearing, increased asymmetric loads on the down lock tab due to continually changing alignment, increased torsional loads on the aft drag link bolt (which is a non-floating bushing), and a "loose feeling" in the nose gear mechanism during taxiing.

The new steel drag links contain NAS75-5-010, 145,000 psi press fit steel bushings, and upgraded MIL-B-81820 aerospace grade spherical bearings with a radial load limit of 8,750 lbs, almost twice that of the original bearing. The spherical bearing also contains an "E" class Uniflon self-lubricating teflon bearing that should never be greased or oiled.

Steel bushings are cryogenically cooled prior to being pressed in. With nearly identical coefficients of expansion of the bearing, bushing, and drag link, the installed bushings and bearings should never lose adhesion or move (even during towing!) and should provide a "tighter" and firmer feeling from the nose gear mechanism when taxiing and landing especially if your aluminum drag link was worn or had loose or floating spherical bearings.

PART DESIGN PHILOSOPHY

In an ideal designed system, during a nose gear overload event (i.e. a hard nose-gear-first landing), all parts of the nose gear mechanism should begin deformation and approach ultimate load simultaneously thereby absorbing a great deal more energy than if just one part reaches failure leaving unused energy absorption capacity in other parts. In the ideal scenario the entire structure absorbs far more energy as multiple parts deform simultaneously, exhibit strain hardening, and deform slower.

Although rarely achieved, it is a design goal. By substantially increasing this part's strength (particularly the over center down-lock tab) more energy will be transferred into the remaining parts of the nose gear mechanism during a hard landing event. The end goal is to have a hard landing event end with deformed nose gear structure requiring replacement of multiple deformed bolt-on landing gear parts rather than incurring a complete gear collapse, replacing an engine and propeller, sustaining a hull loss, or even loss of life. <u>The overriding objective in design and manufacturing was to increase the safety margin of the nose gear system as a whole, and increasing reliability of an already solid and well designed airplane.</u>

ALL COMPONENTS ARE INTERRELATED

Increasing the strength of a system's weakest link will inherently increase loads other components in the system must absorb before a component or system failure occurs.

During an excessively hard landing a component other than the steel drag link may deform and fail before, after, or simultaneously with the strengthened steel drag link. Welds, nuts and bolts, bearings, and fiberglass structure will all experience higher loads and should be rigorously inspected and tested, to include multiple jacked gear retractions and extensions, prior to further flight after an excessively hard landing. This "hard landing event" would likely need to have been so severe as to have collapsed the nose gear had the aluminum drag link still been installed.

With the steel drag link installed, even during normal operations, other nose gear components may experience higher loads. The elastic modulus of steel is substantially higher than aluminum resulting in less of a "cushioning effect" as the steel link's reduced elastically deforms less as it contacts the drag brace's steel support plate. As a result, all parts of the nose gear system should receive increased scrutiny during preflight and condition inspections.

WHY WE ARE OFFERING THIS PART

This steel drag link was originally conceived and designed to be used exclusively on our R&D and technology demonstrator test aircraft to increase the safety margins of the nose gear system. It was only after numerous and repeated requests for this part by other Glasair III owners that the decision was made to initiate a small production run and make it available to Glasair III owners.

WEIGHT

Extensive time was invested to reduce weight through the use of lightening holes and indented milled faces while still retaining higher strength. The completed steel drag link with bearing and bushing installed weighs 9.4 ounces compared with 4.9 ounces for the aluminum part it replaces.

GLASAIR SERVICE BULLETTINS

Several Glasair Service Bulletins (SB) for the Glasair III cover known nose landing gear and related structure issues. Some of these are classified as Mandatory SB (MSB) by Glasair and contain "MSB" in the file name. Although not all inclusive, to ensure all parts of the nose gear system are considered for soundness and security we recommend at least the following nose gear related SB be reviewed for applicability to your aircraft.

Bulletins: SB95, SB95A, MSB100, MSB119, MSB129, SB141, SB143, SB160

A complete listing of all SB and Service Letters can be downloaded from the Glasair web site.

http://glasairaviation.com/glasair-advisories-bulletins/

DISCLAIMER

THIS PART IS NOT PMA APPROVED, NOT CERTIFIED BY ANY STANDARDS AUTHORITY, IS BEING OFFERED WITHOUT ENGINEERING OR STRUCTURAL STRENGTH REPRESENTATIONS, DOES NOT CONTAIN AN ENGINEERING STAMP, AND IS FOR EXPERIMENTAL USE ONLY. THIS PART IS NOT WARRANTED FOR MATERIAL, DESIGN, OR WORKMANSHIP AND IS OFFERED IN AN "AS IS CONDITION".