MacLean Fogg Fastener Challenge: Novel Impact Attenuator (IA) attachment

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IA Mounting Status Quo

RIT Racing's previous car (F24) had 4 $\frac{5}{16}$" AN bolts fastening the threaded insert (keysert) in the IA to the Chassis Front Bulkhead. The IA also holds the bulky and somewhat heavy front wing, so aligning it is difficult and uncomfortable

Pros with traditional bolted joint

- This bolted joint functioned well enough, and when done correctly was time and effort efficient during the manufacturing phase of the car

Cons with traditional bolted joint

- Nosecone and chassis were aligned together permanently
  - Nosecones were not interchangeable between cars, and repairs to the IA were very difficult if not impossible
- Very time consuming to attach
- Very time consuming to remove
- Minimal clearance for socket
  - Rounded bolt heads
- Various alignment issues

Discovering the Issue

- After a long season of testing, and 3 competitions, the continual threading and unthreading of a difficult to align connection began to strip the keyserts
  - Very sensitive to first few threads in one particular corner
  - While packing to leave that year's final competition, 2 out of the 4 inserts were discovered to be heavily stripped and borderline useless
- Bolt heads constantly rounded due to socket clearance
- Bolt threads stripped due to deformed inserts
- Attaching the IA/front wing became a 20 minute ordeal of trying to get bolts to thread

Repair?..

- After the damage had been done, the most permanent way to repair was drilling out the keysert, potting the hardpoint, drilling and tapping the repaired hole, then remounting a keysert which will eventually strip the same way.
  - Alignment was an issue with this mounting, as not all bolts were perfectly parallel with one another and were side loaded as the IA was being inserted.
- Fortunately, this was the last planned competition for this particular chassis, so no repairs were required

Anti-Intrusion plate showing which fastener to thread first

Additional Impetus for Creation

- In 2017, the Formula SAE rule book had a rule change with regards to IA mounting. In particular the amount of bolts for attachment increased from 4 to 8
  - **T3.20.4** The accepted methods of attaching the Impact Attenuator Assembly, Impact Attenuator and Anti Intrusion Plate are:
    - Welding
      - Not possible with composites
    - Adhesive
      - Closes off the pedalbox region from easy servicing
    - **Bolted joints,** using a minimum of eight **(8)** 5/16” SAE Grade 5 bolts
      - Allows removal for easy servicing of combined IA, nosecone, and Front wing mounting assembly

5 Design Goals

1. Easy to implement with current Chassis and IA mold geometries
2. Allow for quicker removal and attachment to allow better serviceability of pedalbox or front wing aerodynamic devices, or removal of front aero to prevent damage in transport
3. Have the mounting setup be strong, safe, and “idiot proof” so anyone can attach front wing with simple instruction
4. Jigging that is simple and time effective
5. Allow some adjustment to allow adjustment of IA to align with the planes of the chassis (aesthetic)

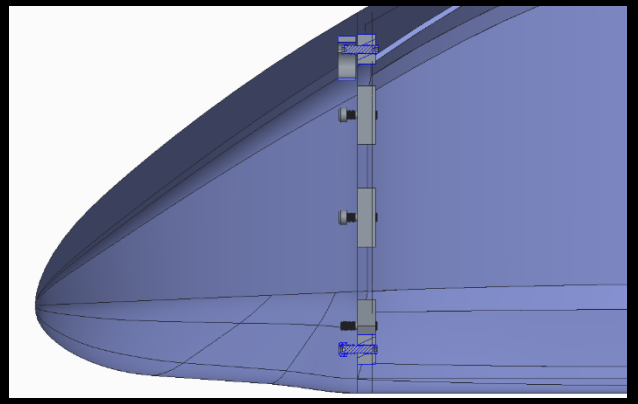
How to attach a front wing: Before vs After

Before

1. Get 2 people to help align IA/wing (left and right of 4’ wide 15+ lb wing) and hold Anti-intrusion plate to the IA with tape
2. Thread easy to strip bolts in a specific order by hand into easy to strip inserts
3. Carefully tighten fasteners evenly to prevent bending any bolt, keeping in mind clearance is too tight for most sockets so a combination wrench is needed for a while
4. Remove tape that holds AI to IA

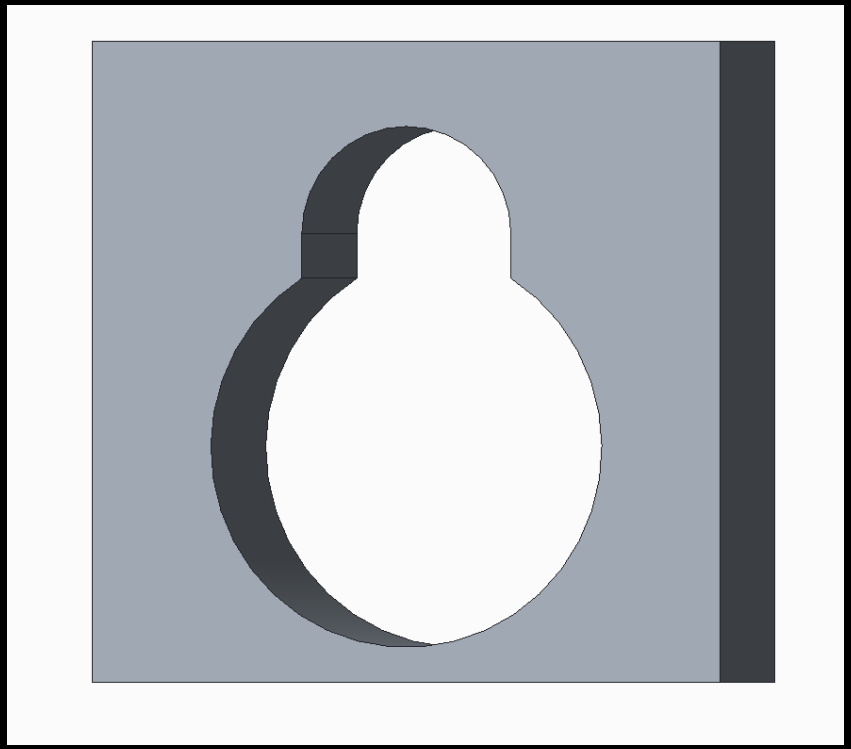
After

1. Place IA on mounting studs, aligning nuts through clearance holes in hardpoints (IA side)
2. Push towards ground from top of nose cone sliding the nuts to clamp the IA while also aligning nosecone to chassis
3. Rotate set screws with angle flexible allen ball socket



Solution: Hardpoint

- Hardpoints for the impact attenuator were machined
  - Prototrak programmable mills made machining take less than an hour for 8 hardpoints with easy scalability
- Large diameter circle is clearance to large OD of nut
- Small diameter circle to allow nut to clamp to large enough area
- Down force pushes the screw towards top of small diameter circle

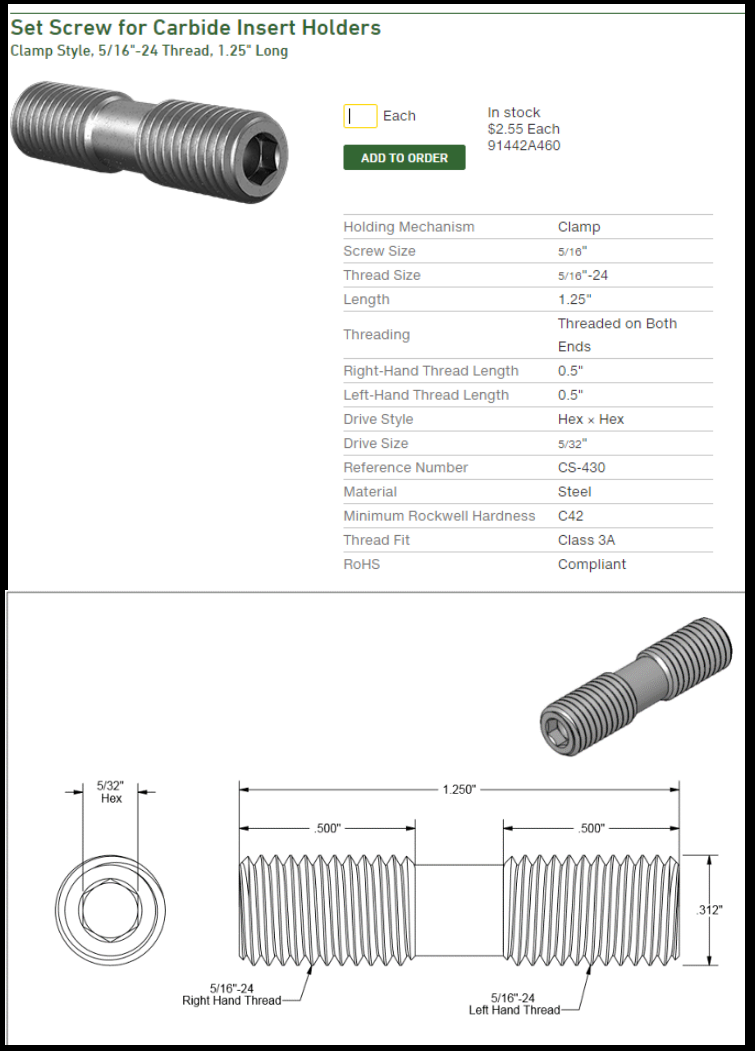


Jigging

- Jigging
  - One jig to align attachment holes in IA/nosecone mold
    - Waterjetted in <5 minutes out of scrap Al plate material
  - One jig to drill holes on front of chassis
    - Able to use same piece of scrap for a waterjetted drill guide aligning all 8 holes accurately
  - Alignment on final car has .025” of slop that allows the nosecone to be aligned correctly before clamping down
    - Multiple nosecones have been made and they are interchangeable across chassis’ with no problems!

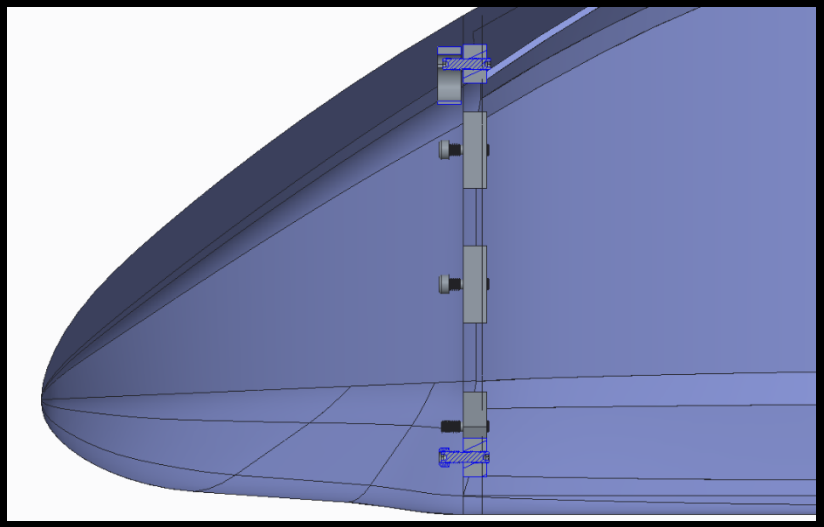
Screw/fastener

- The screw used is a $\frac{5}{16}$"-24 set screw purchased from McMaster Carr
  - Originally intended for holding carbide inserts on lathe tools
  - Extremely high strength (180ksi Ultimate strength!)
  - High precision Class 3A fit
  - Extremely unique set screw with one side that is right hand threaded
  - Hex/allen key driving for fastening
  - Only $2.55 per fastener!



Explanation of screw

- Fastener is rotated counterclockwise with ball end allen key socket
  - Allows clearance and removes fear of rounding fastener
- As fastener travels backwards with respect to the front of the car, the nut/washer begins clamping on the IA hardpoint
  - As the nut/washer begins to bite/grab onto the IA hardpoint, the left hand threaded part of the insert begins pulling the set screw twice as quickly as it would otherwise



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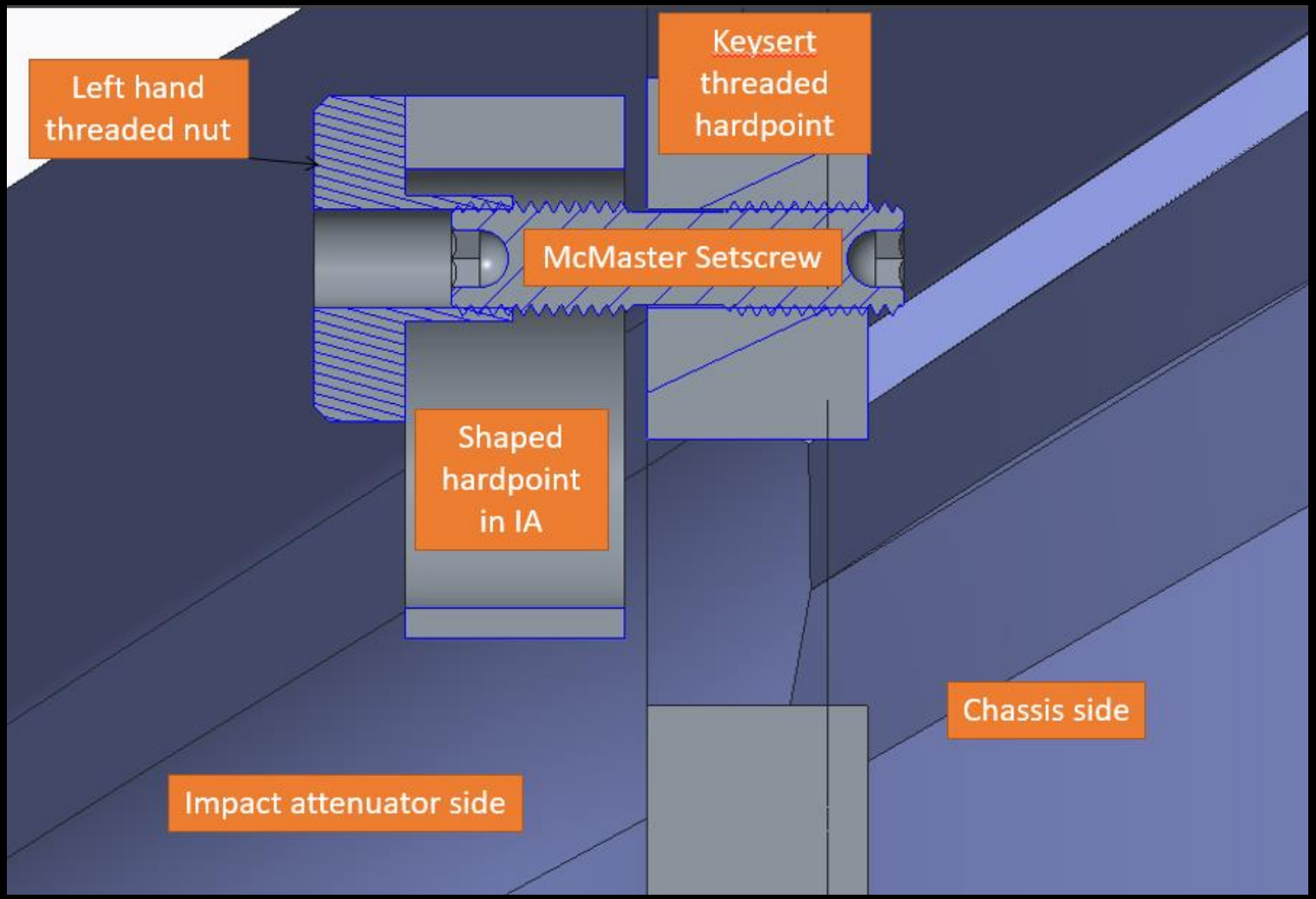
Blowup of assembly



Results after working with the new mounting

All 5 goals were met or exceeded expectations!

1. The mold geometries for all composite parts were retained (chassis and IA)
2. IA/wing can feasibly be removed in 1 minute or less, and fastened in the same amount of time. Fasteners take about ¾ to 1 full turn to go from loose and allowing the IA to slide on to being fully tightened
3. IA/wing mounting has changed from a three person balancing act of holding a wing and trying to thread bolts to a one person activity that anyone with hand tool skills can operate effectively
4. Jigging took one machine operator less than a day to finish
5. Aesthetic alignment is improved over previous design with the new ability of IA interchangeability

Appendix: Excel Calcs

Shear Equiv	
Bolt Minor Diameter	0.272 in
Shear Allowable	75000 psi
Force	4358 lbf
Number of Bolts	8
Total Shear	34864 lbf

Margin
191%

Friction	
OD	0.900 in
ID	0.350 in
Total area for friction	0.540 in^2
Yield of Fastener	160000 psi
Clamp force 5/16-24	25635 lbf
Static Mu of CFRP on Al	0.6
Force per nut	8305 lbf
Number of Bolts	8

Total Perpindicular force to dislodge IA Mounting
66442 lbf

Friction with washer/nut vs shear of rules required Grade 5 bolts

Appendix: Excel Calcs Cont.

# of Fasteners on IA		Source for Calcs			
8					
McMaster Set Screw		**Aluminum Nut**		**Chassis FBH Insert**	
External Thread Pullout		**Internal Thread Pullout**		**Internal Thread Pullout**	
K_n max	0.261"	E_n max	0.284"	E_n max	0.284"
E_s min	0.283"	D_s min	0.313"	D_s min	0.313"
L_e	0.375"	L_e	0.375"	L_e	0.500"
n	24	n	24	n	24
Shear Area	0.24 in^2	**Shear Area**	0.33 in^2	**Shear Area**	0.44 in^2
UTS	191000 psi	**UTS**	45000 psi	**UTS**	120000 psi
Yield	170000 psi	**Yield**	40000 psi	**Yield**	105000 psi
Approx Ult Load	46770 lbf	**Approx Ult Load**	14757 lbf	**Approx Ult Load**	52470 lbf
Kips	46.8 kips	**Kips**	14.8 kips	**Kips**	52.5 kips
Approx Yield Load	41627 lbf	**Approx Yield Load**	13117 lbf	**Approx Yield Load**	45911 lbf
Kips	41.6 kips	**Kips**	13.1 kips	**Kips**	45.9 kips
Total pullout max load		**Total pullout max load**		**Total pullout max load**	
374.2 kips		118.1 kips		419.8 kips	
Total pullout load till yield		**Total pullout load till yield**		**Total pullout load till yield**	
333.0 kips		104.9 kips		367.3 kips	

Thread tearout calcs to sanity check the connections