

**A Method of Desensitizing Wooden Propeller Hub
Mounting Bolt Security To Environmental Effects and
Sub-Optimal Maintenance Techniques**

Or

**How To Keep Your Wood Prop
On Your Plane With Less Work**

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July 31, 2008

2:30 PM – 3:45 PM

Forum Tent 06 – Utah Valley University Pavilion

What Will I Talk About?



- Characteristics of Wood Props
- Need for Maintenance
- Proposed Solution – Representation / Theory
- Specific Solution
- Prior Art / Proposals
- Pre-Flight Testing
- Flight Testing
- Current Configuration
- Gyroscopic Issues
- Increased Robustness / Decreased Sensitivity
- Cost / Weight Penalty
- Availability
- Questions / Answers

Characteristics of Wood Props



- Relatively soft
- Low crush strength
- Low stiffness
- Susceptible to moisture / humidity / shrinkage / expansion



Need For Maintenance



Examples of Wooden Propellers:

- Sensenich – 50 hrs or annually
- Hertzler – every 25 hours, anytime going between different climates
- Jabiru – every 25 hours
- Miles Gemini – every 10 hours

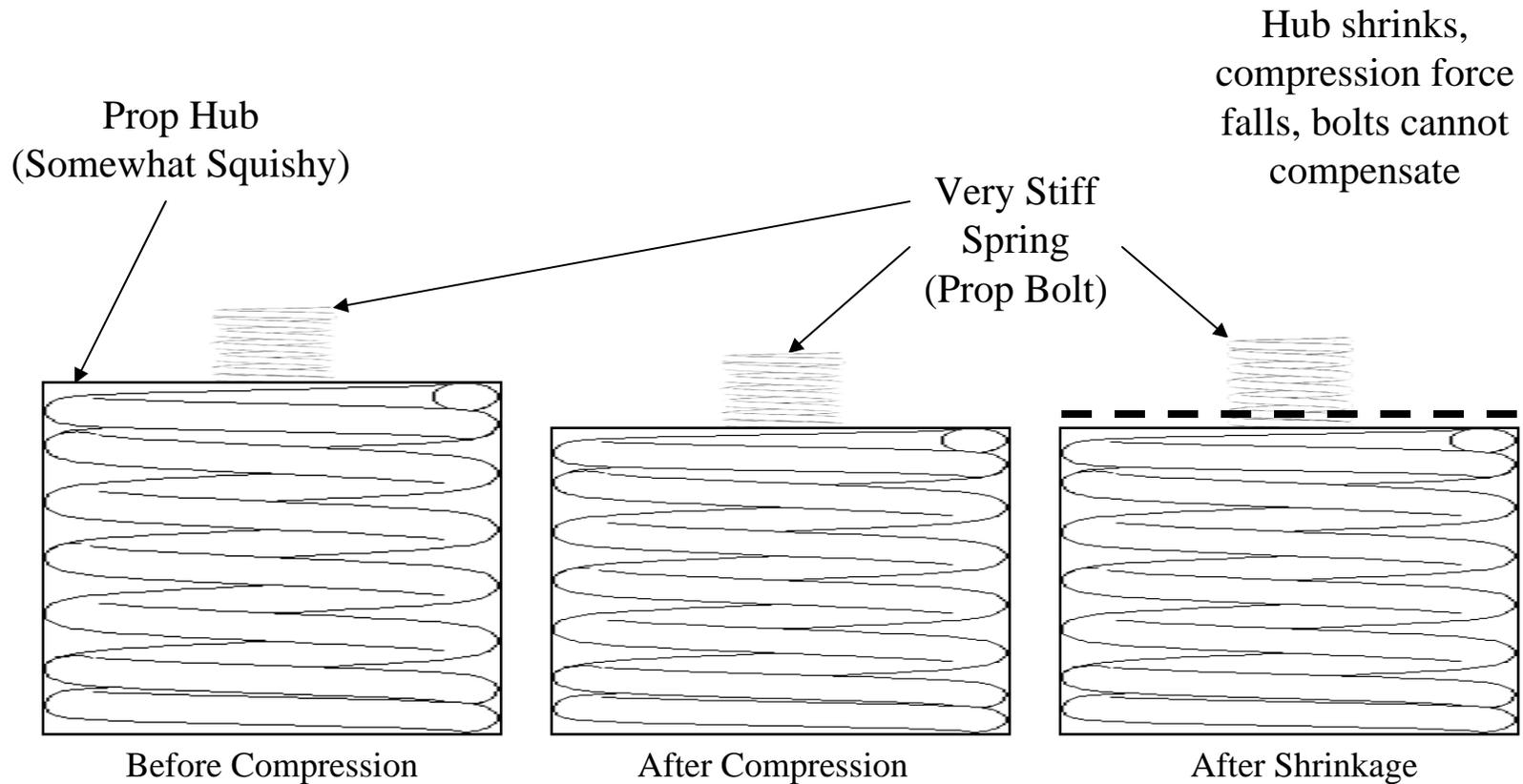
Technique (not usually specified):

- Remove safety wire
- Loosen bolt first to break static torque
- Ensure movement – measure torque while turning

Proposed Solution – Representation / Theory - 1



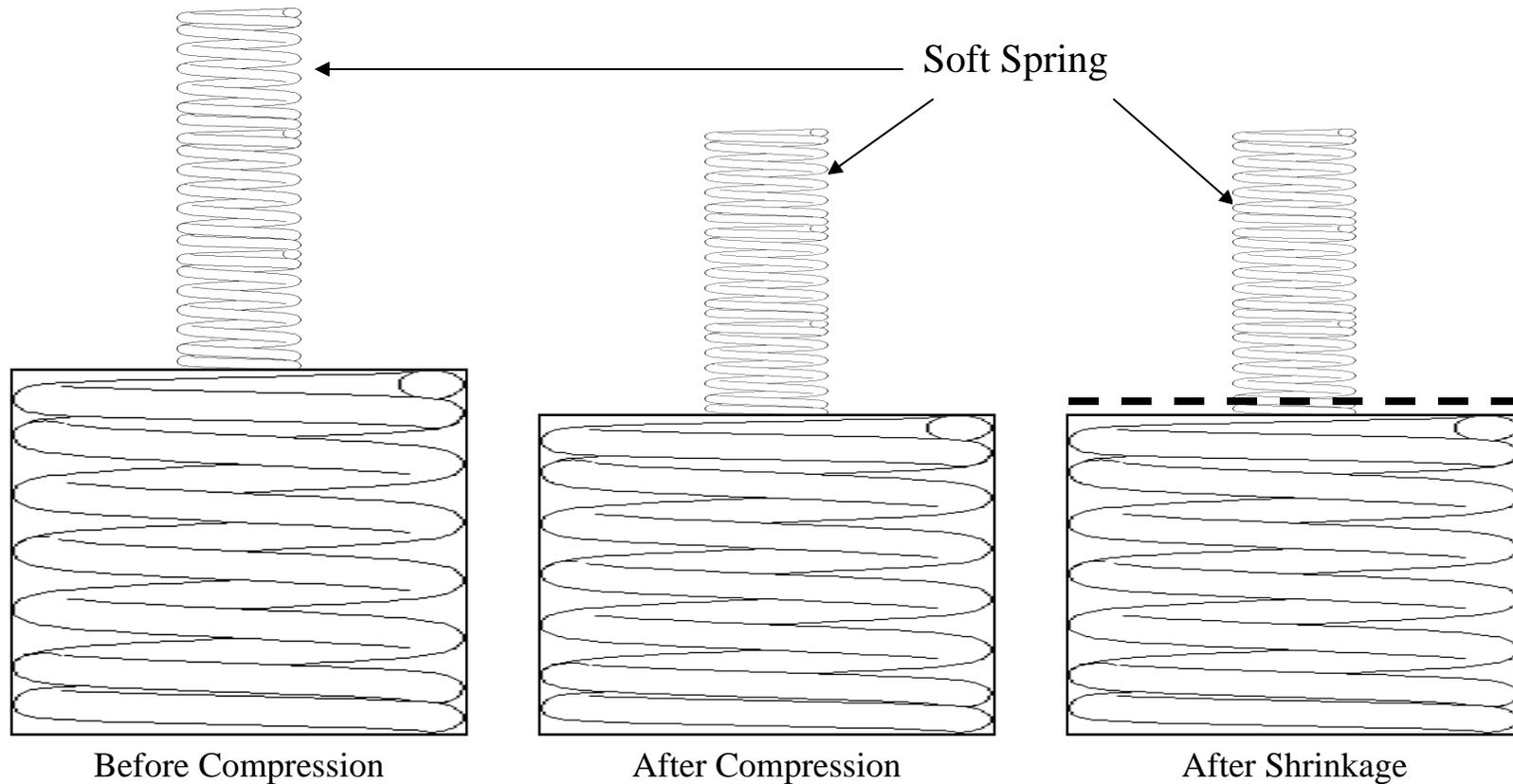
- Prop Bolts very stiff – Prop Hub size determines force



Proposed Solution – Representation / Theory - 2



- Same motion of hub
- Small change in spring force – SOFTER SPRING DETERMINES FORCE CHANGE

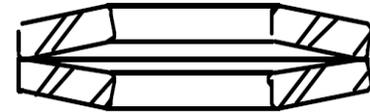


Specific Solution

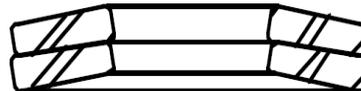
- Belleville Washers
- Flexible arrangements
 - use serial stack
- Force/deflection curves adjustable – can obtain any force/deflection required



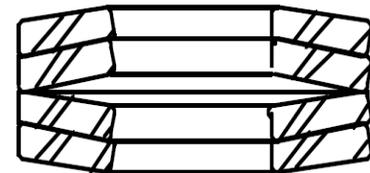
SINGLE BELLEVILLE
FLAT LOAD = 1 X Fw
DEFLECTION = 1 X h



TWO IN SERIES
FLAT LOAD = 1 X Fw
DEFLECTION = 2 X h



TWO IN PARRALLEL
FLAT LOAD = 2 X Fw
DEFLECTION = 1 X h



SERIES-PARALLEL
FLAT LOAD = 2 X Fw
DEFLECTION = 2 X h

Prior Art / Proposals

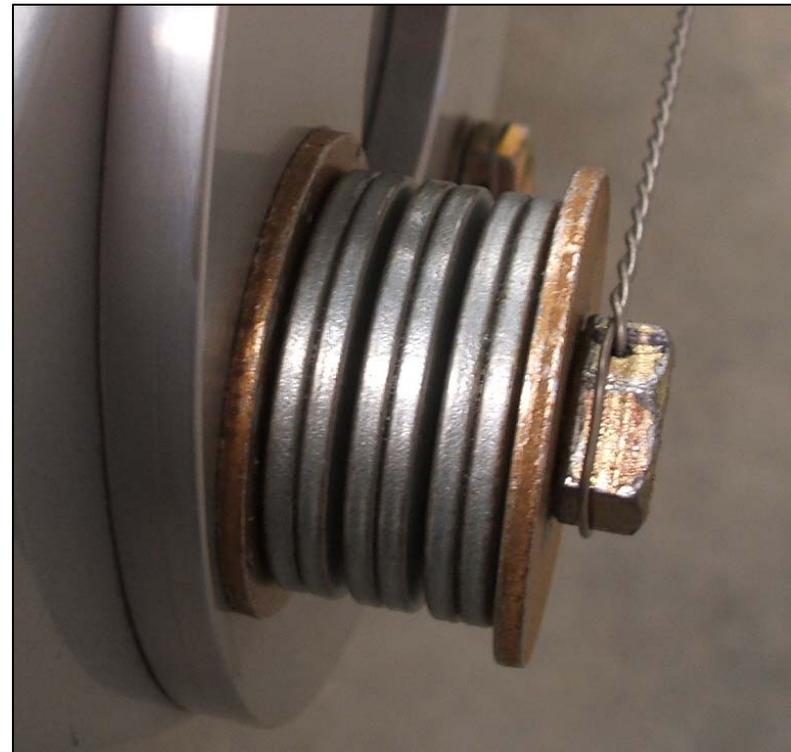


- Jabiru - recently switched to belleville stacks on certain engine prop combinations
- Miles M65 Gemini w/Cirrus Minor II Engines, from 1947 – used belleville stacks
- Paul Lipps / Vance Jaqua – belleville stacks installed on Lancair 235 w/O-320
- Burt Rutan proposal 25 years ago – never tested
- Independently proposed to me by 3 sources – c-a mailing list; web forum; co-worker

COZY MKIV Installation



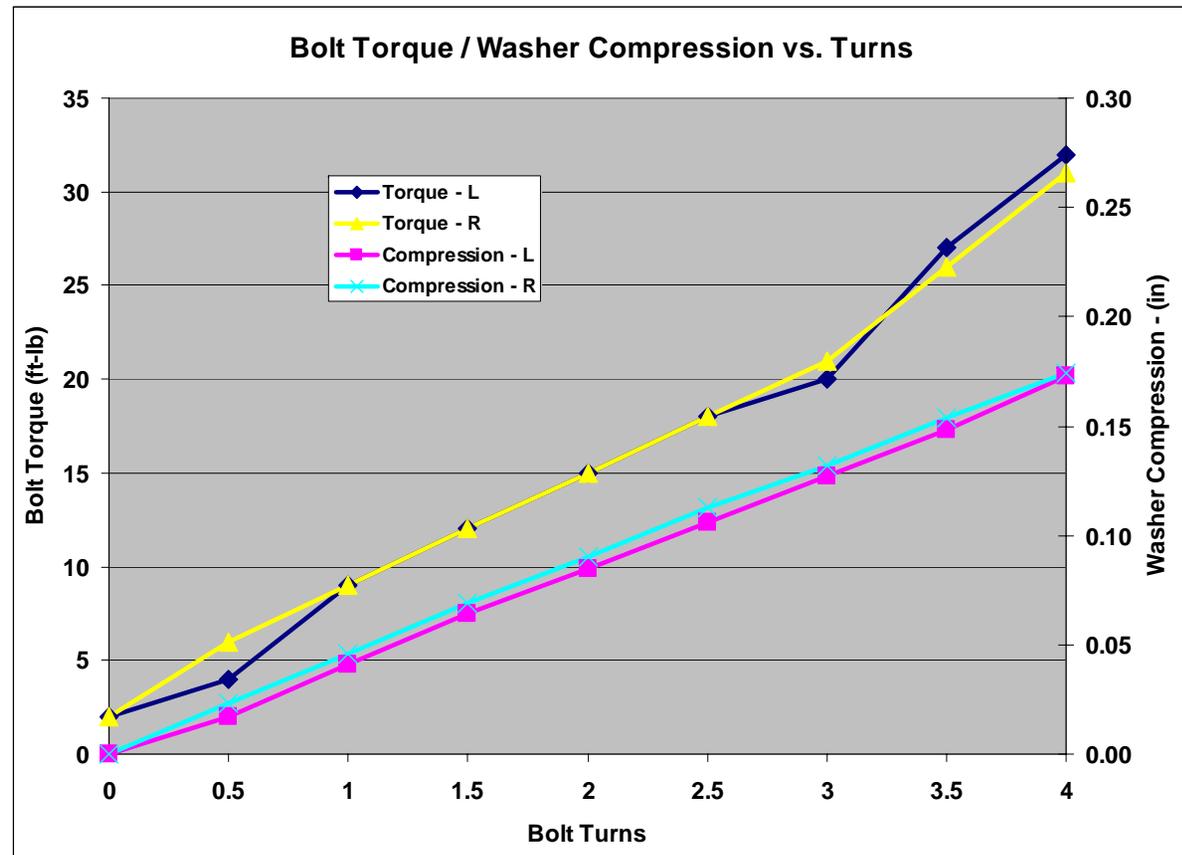
- Took proposals, did calculations, picked hardware
- Determined 6-stack would provide more than adequate expansion / shrinkage capability



Pre-Flight Testing - 1



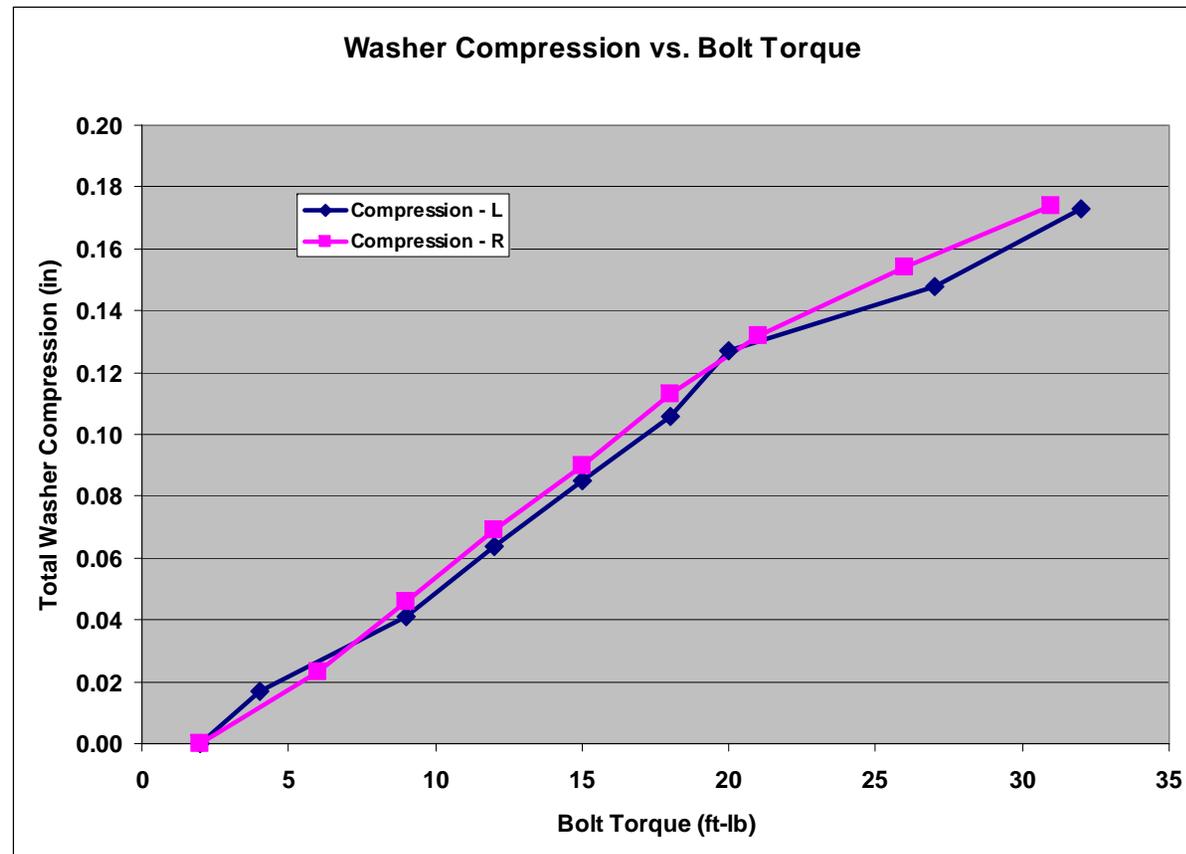
- Find Hardware
- Two bolts have stacks of 6 bellevilles captured between two wide area washers – 4 standard bolts
- Can see good linearity



Pre-Flight Testing - 2



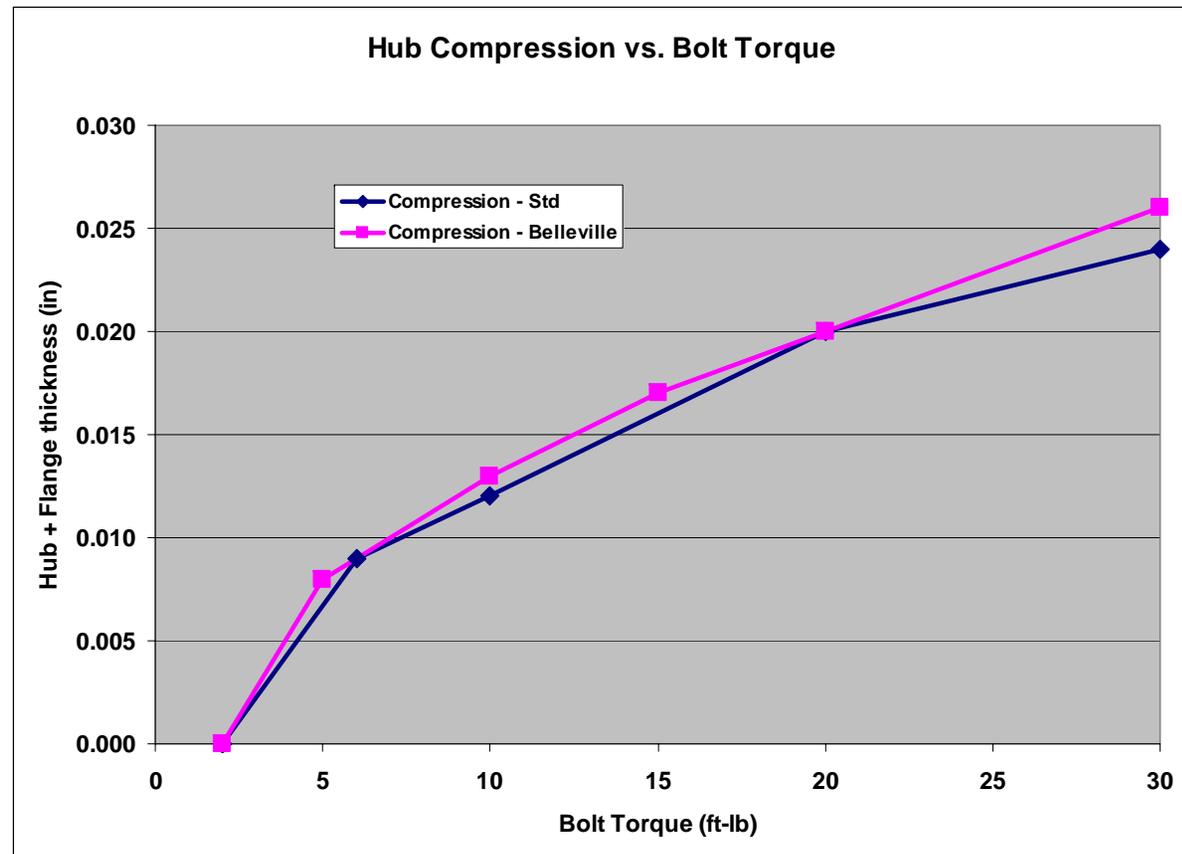
- Remove “turns” from the equation – just show washer compression vs. applied torque
- Still very linear



Pre-Flight Testing - 3



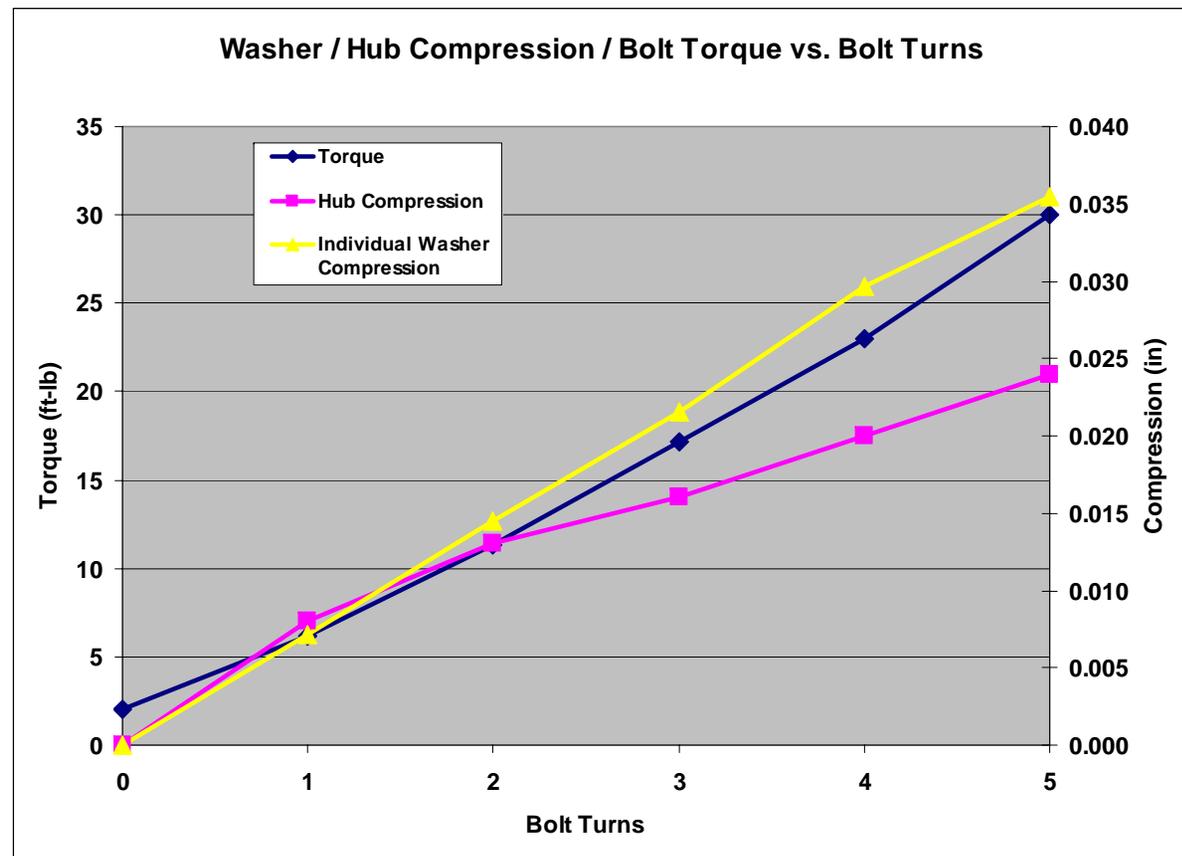
- Switch from six std. bolts to six bolts – all with Belleville washer 6-stacks
- Change in slope as “slop” is taken out of system (both types of bolting systems) – then more torque for same compression needed



Pre-Flight Testing - 4



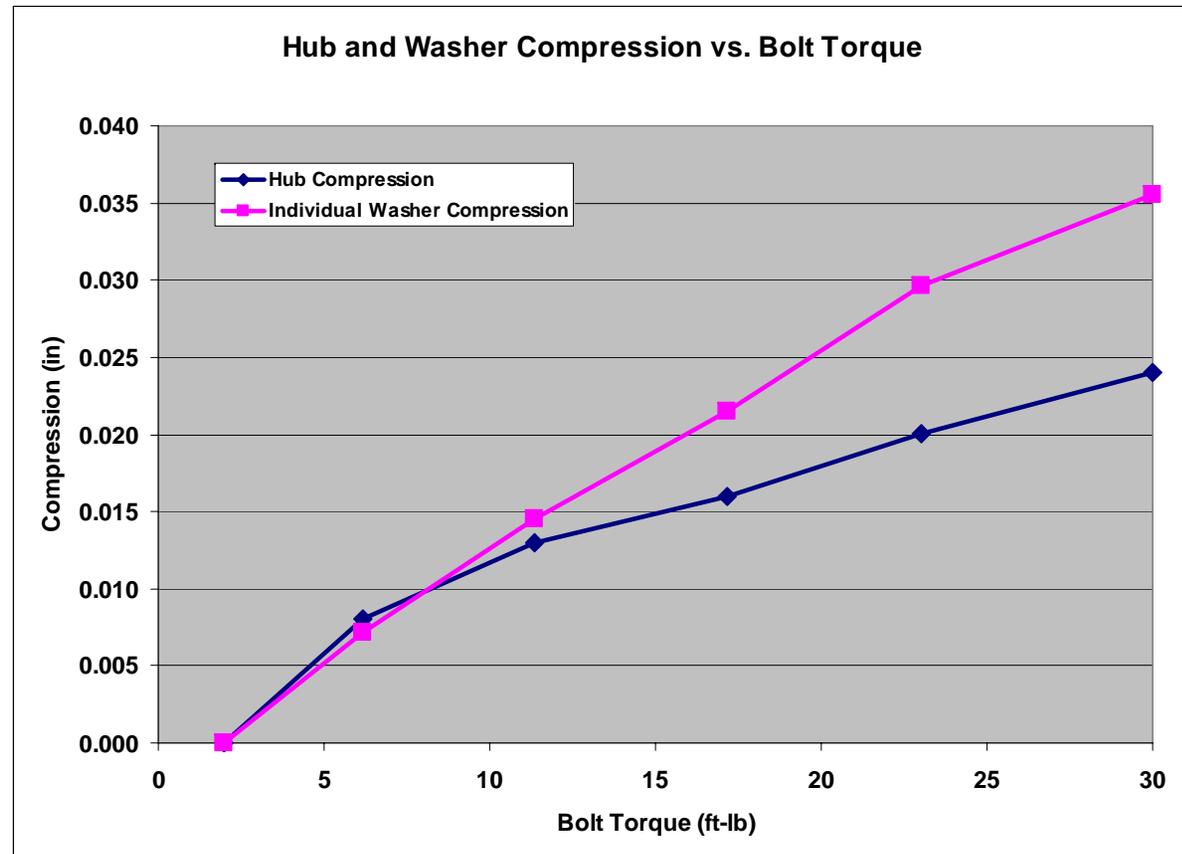
- Six bolts with belleville washer 6-stacks
- Very linear torque and compression with bolt turns



Pre-Flight Testing - 5



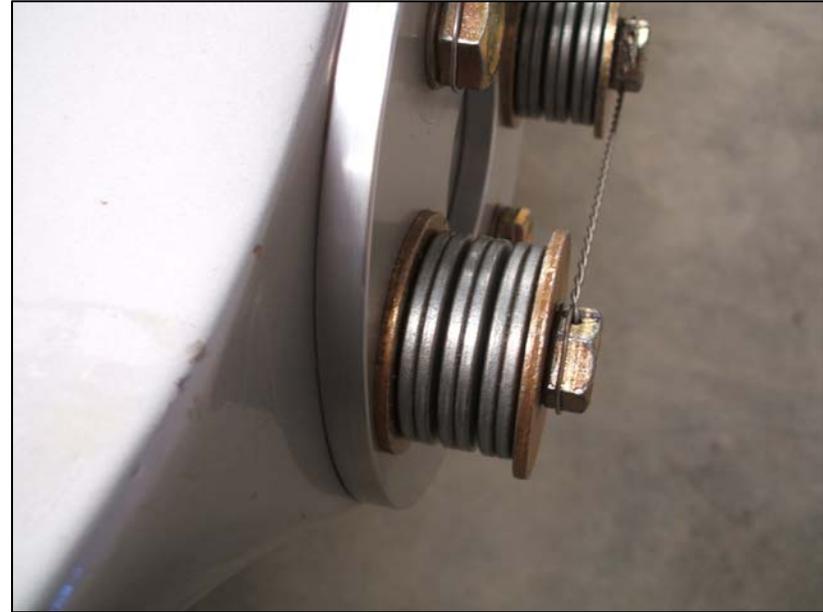
- Same slight change in slope as “slop” is taken out
- Still predictable and relatively linear with Bolt Torque
- Might be easier to measure turns rather than torque, however



Flight Testing - 1



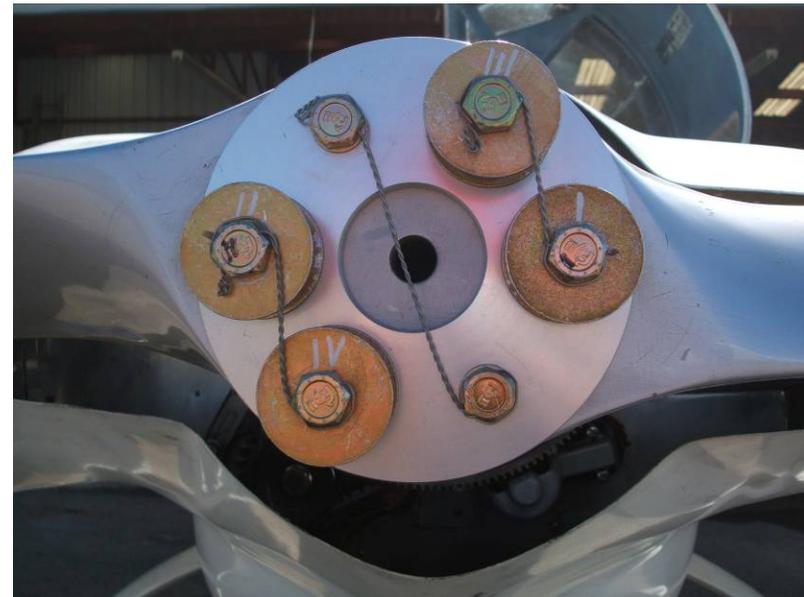
- First few flights – two bolts with bellevilles – four standard bolts
- Calcs show prop will stay even if two bolts don't
- See washers NOT completely compressed – allows for shrinkage AND expansion of Prop Hub
- No difference from standard installation perceived - ~3 flight hours accumulated in this configuration at various speeds, RPM, flight attitudes – near 1 million cycles for fatigue



Flight Testing - 2



- Next few flights – four sets of belleville washers, two standard bolts
- Have confidence based on previous flight hours
- Run another ~3 hours – build ~2 million cycles on first set, ~1 million on second set
- Again, fly various RPMs, flight attitudes, speeds, G-loading



Flight Testing - 3



- Next set of flights – all six bolts with belleville washer stacks
- Built more confidence based on previous flights
- Run another ~3 hours – build ~3 million cycles on first set, ~2 million on second set, ~1 million on third set
- Again, fly various RPMs, flight attitudes, speeds, G-loading



Flight Testing - 4



- Remove two bellevilles from each stack – now have 4/bolt
- Run another ~40 hours – build ~13 -15 million cycles on all belleville washers
- Again, fly various RPMs, flight attitudes, speeds, G-loading



Current Configuration



- Using 7” bolts – could reduce to 6.5” and remove hardened washer to save ~0.1 lb.
- Added AN3 bolts to FRONT of crush plate
- Will be able to add spinner backplate / mounting structure WITHOUT having to remove/touch prop bolts
- Don’t have to have backplate BETWEEN prop and prop extension



Gyroscopic Effects and Belleville Washers

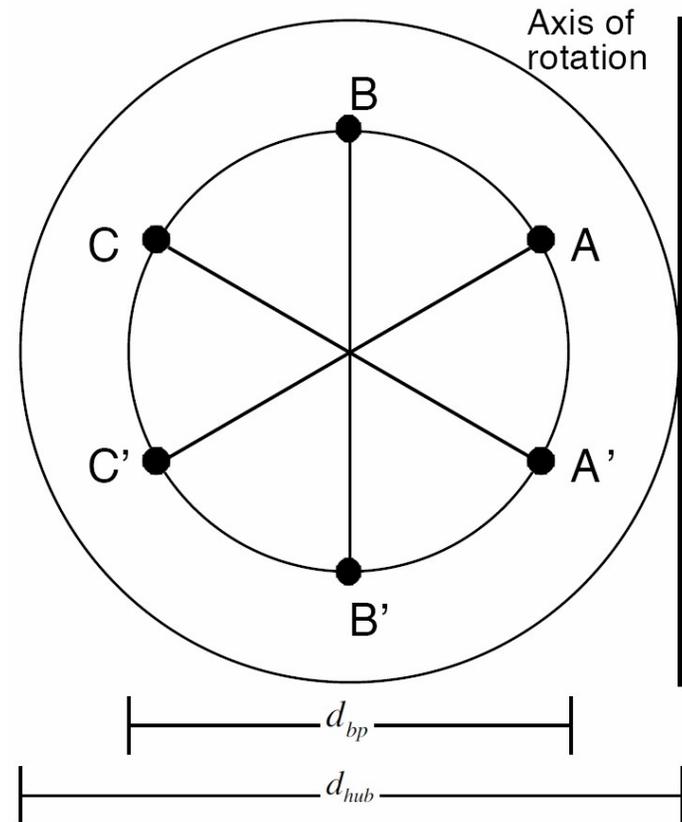


Analysis by David Dannemiller

Assumptions:

- Weight of Prop: 16 lb.
- Prop Hub Dia.: 7 inch
- Prop Diameter: 64 inch
- Maximum Pitch/Yaw Rate: 90 deg/sec
- Prop Bolt Tension: 3000 lb.

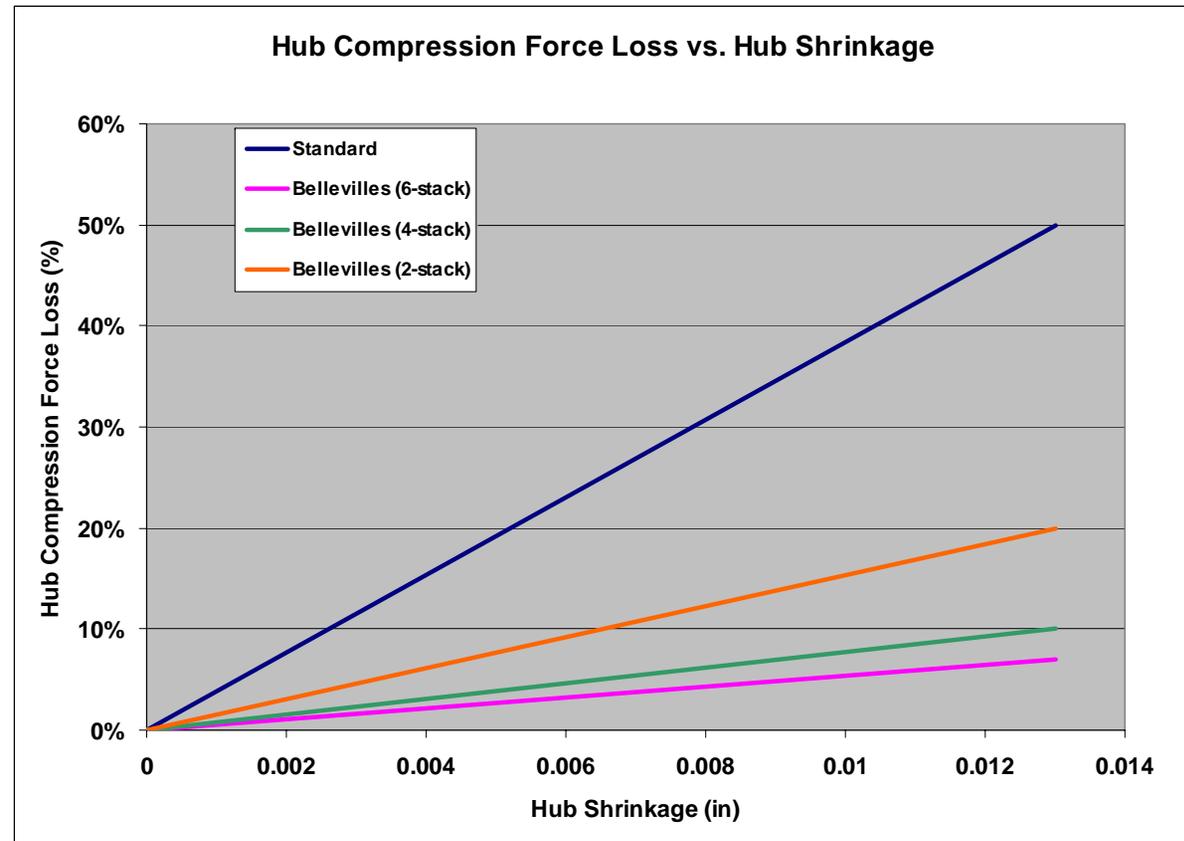
Safety Factor: 9



Increased Robustness / Decreased Sensitivity



- Maintenance simplification (measure spacing, # turns)
- Maintenance frequency reduction (Jabiru – from 25 hrs. to 1/yr. example)
- Safety enhanced



Cost / Weight Penalty



- ~2.5 lb for 1/2" Bolt SAE-2 Flange with 7" Crush Plate and 4 washers/stack (current configuration)
- ~1.75 lb. for 3/8" Bolt SAE-1 Flange with 6" Crush Plate and 4 washer/stack (currently in testing)
- ~ \$120 gets replacement bolts, bellevilles, flat washers

Availability



- Washers, etc.
- Currently configured for 1/2" bolts and 3/8" bolts - others may be tested in the future.
- I can supply Bellevilles at cost+; Prop Bolts available from Saber MFG, washers from ACS, Wicks, etc.

Questions / Answers



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