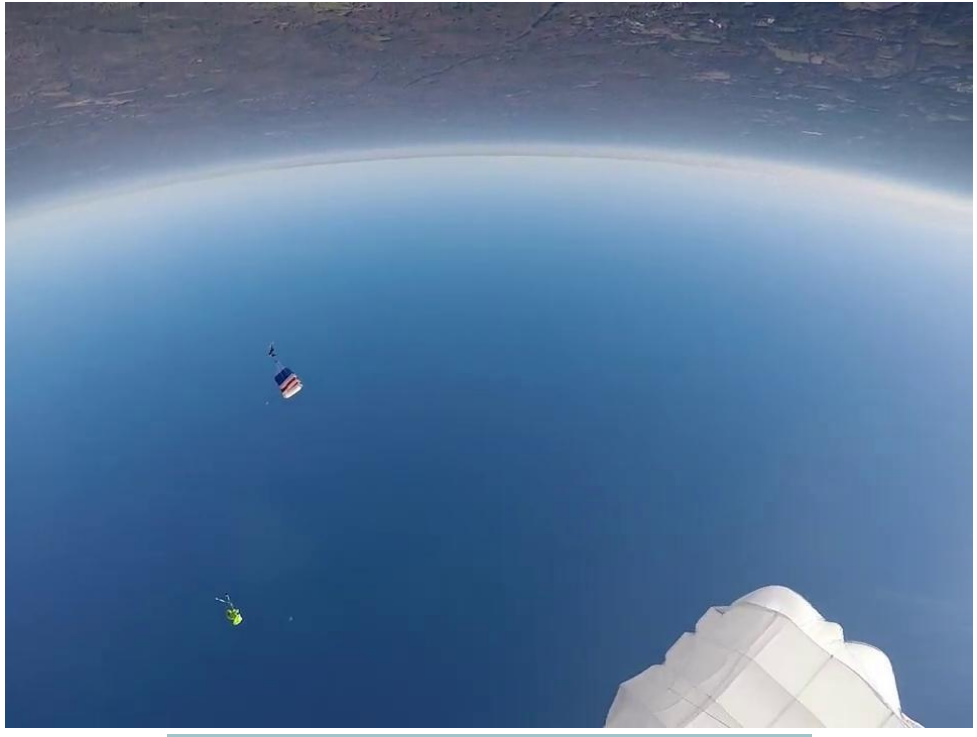
Testing and Analysis of Components for 3-Ring Systems



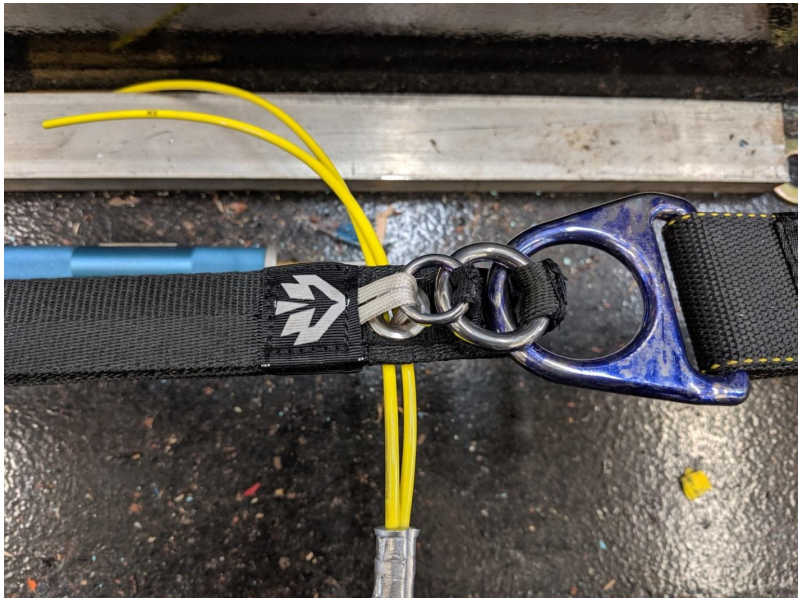
VIDEO

Presented by Patrick Pollin, Tim Tylaska, and Tom Dixon

Tylaska MARINE & AEROSPACE

Tylaska Components for 3-Ring Release

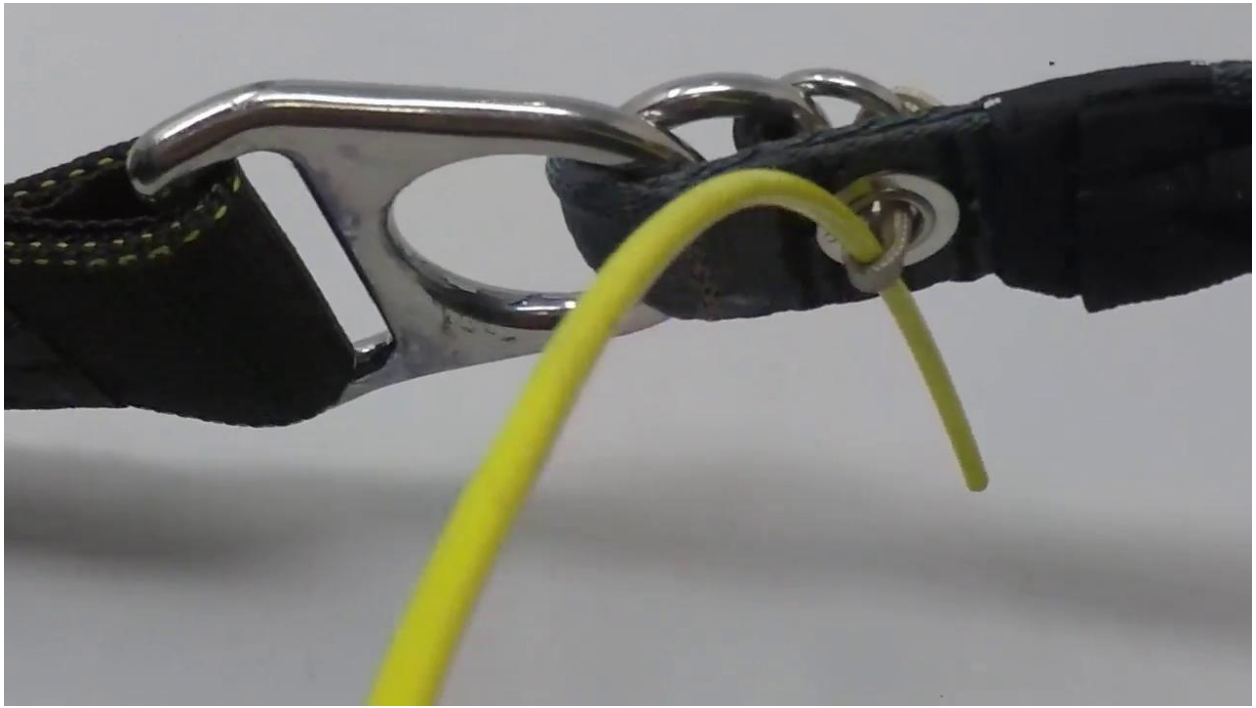
- Tylaska has developed new stainless steel components to be used with standard Mini 3-Ring release systems
- We are presenting a view of our analysis and development to provide information on the safety of these new components



Tylaska
MARINE & AEROSPACE

Tylaska Components for 3-Ring Release

- ***Demonstration***



OUTLINE

Tylaska MARINE & AEROSPACE

Stainless Steel 3-Ring Testing and Analysis

This presentation will include:

- Background Information
- Manufacturing Process
- D-Ring Verification
- Middle Ring Verification
- Small Ring Verification
- Assembly Testing
- Summary

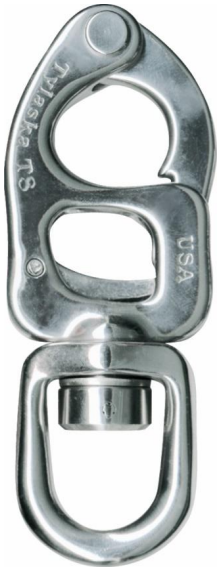
Tylaska MARINE & AEROSPACE

Tylaska 3-Ring Configuration

- Raw Material: UNS31600 Type 316L Stainless Steel
- Process: Cold Forging
  - No heat treat required
- Finishing: Highly polished gloss stainless
- Quality
  - Destructive test samples from every lot with third party verification.
  - Tylaska is registered to the Aerospace AS9100D quality management standard

Tylaska Background

- Tylaska is a USA manufacturer that has been producing high performance stainless steel quick release systems for over 25 years
- Tylaska has a Quality Management System registered to the aerospace standard AS9100D with annual third party audits



Tylaska
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Austenitic Stainless Steel

- Unlike traditional hot forging, cold forging substantially increases yield and tensile strengths without the need for heat treating.
- Cold forging can also create a strong outer shell while maintaining a more ductile inner core
- Strengthening inherent to the cold forging process removes the danger of a part unintentionally missing heat treatment
- Parts maintain superior surface finish by avoiding hot forging scale

Highly ductile failure of an austenitic 316L stainless steel piece

Tylaska
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Tylaska Cold Forging Process

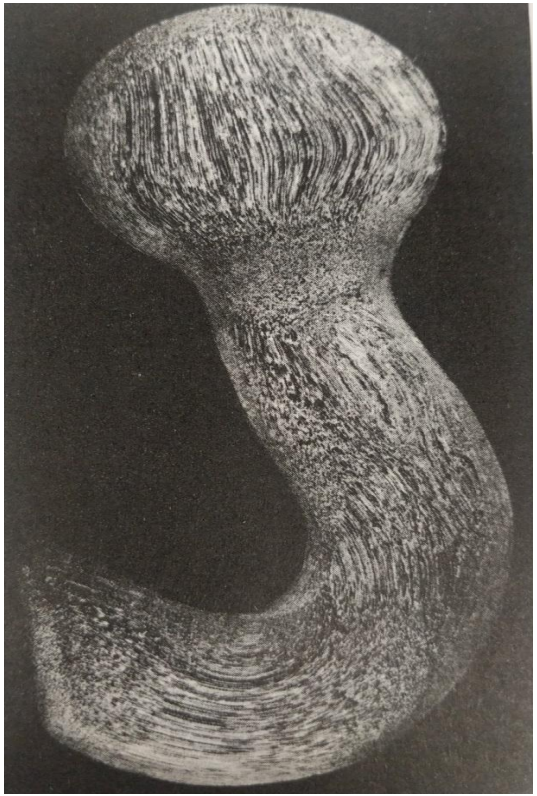
- Austenitic stainless steel can be formed at room temperature using tremendous pressure
- Strain hardening takes place as the raw material deforms and flows under pressure to fill the shape of the mold
- Over 2 million pounds of force are applied to transform the raw material into the desired shape.

Tylaska
MARINE & AEROSPACE

Performance Evaluation

A wide variety of tests are used to evaluate the structural integrity of the forgings

- Metallurgical inspection
- Static tests
  - Proof load
  - Destructive tensile test
  - Low temperature ductility test
- Dynamic Tests
  - Fatigue test
  - Impact loading
- Real world tests
  - Test cut-aways, skydive cut-away



Tylaska MARINE & AEROSPACE

Quality and Manufacturing Traceability

- AS9100D Quality Management System
- Stringent In-House testing
- Third-Party testing on every lot

Tylaska maintains lot traceability on all parachute hardware components.

- Traceability and chemical certs of all materials used
- Manufacturing process traceability
- In-house destructive testing on every manufacturing lot
- Third party destructive testing on every manufacturing lot

HARDWARE EVALUATION

Tylaska
MARINE & AEROSPACE

Structural evaluation of Tylaska rings vs. existing hardware

D-RING: OVERVIEW

Tylaska MARINE & AEROSPACE

Analysis of Parachute D-Rings

- Standard Plated Steel 4140 D-Ring (Raw material MIL-S-5626 steel)
- Tylaska RD46
- CWH SR-8

Tests to be discussed

- Proof Load & Tensile test
- Fatigue Test
- Impact Test
- Low Temp. Tensile
- Surface Hardness

- Tensile test sample

D-RING: DIMENSIONS

Tylaska MARINE & AEROSPACE

Dimensions of Common D-Rings

Part Type	Raw material	Part no.	Manufacturer	Thickness (mm)	Slot width (mm)	Inside diam. (mm)
Stainless steel D-Ring	316L Stainless Steel	RD46	Tylaska	6.3	44.7	33
Stainless steel D-Ring	316L Stainless Steel	SR-8	CWH	6.3	44.5	33
4140 Steel D-Ring	4140 Steel	Mini D-Ring	Various	6.5	44.7	33

Tylaska MARINE & AEROSPACE

Failure Analysis: Tensile Test

- Cold forged stainless D-Ring at tensile failure; approximately 11,000 lbf

ANALYSIS: D-RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Tensile Test

CWH SR-8

Tylaska RD46

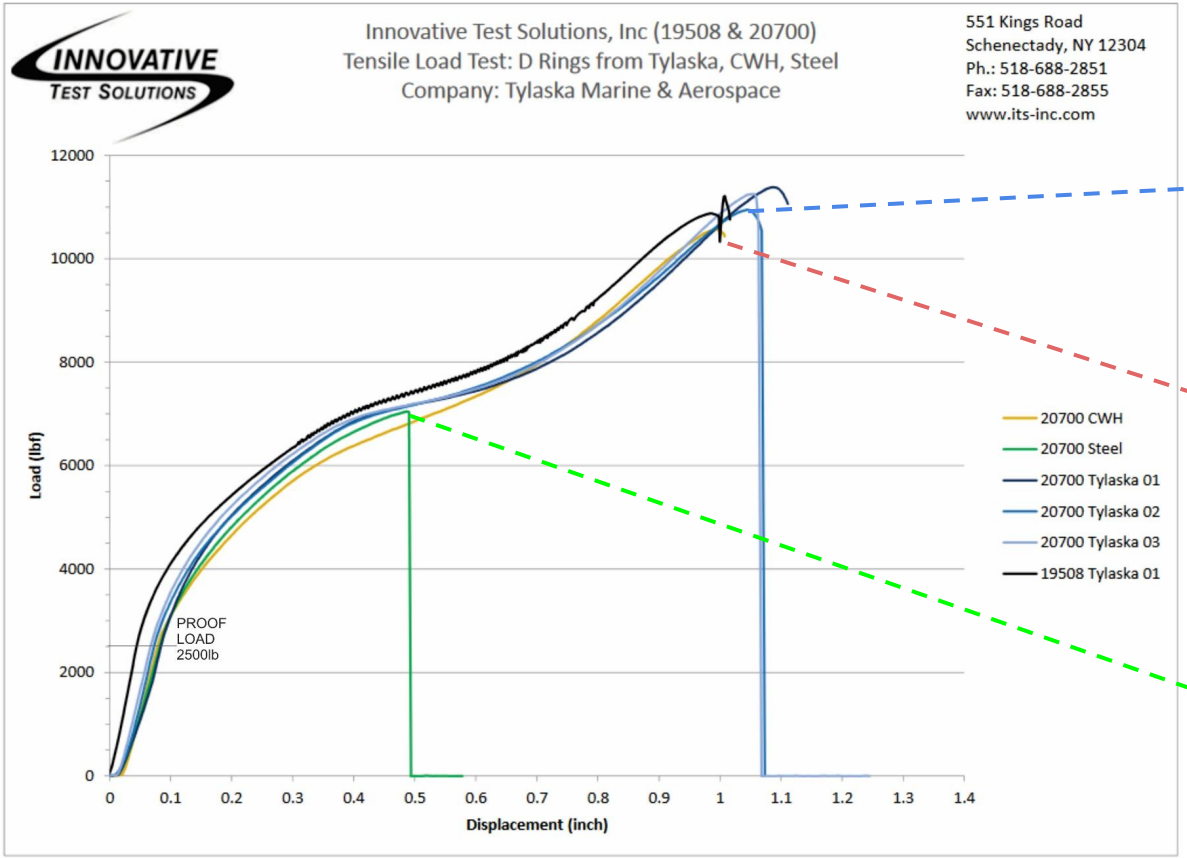
Standard 4140 Steel

Type	Sample	Breaking Load (lbf)
D-Ring	CWH SR-8	10575
D-Ring	TYLASKA RD46 test sample-01	11386
D-Ring	TYLASKA RD46 test sample-02	10949
D-Ring	TYLASKA RD46 test sample-03	11256
D-Ring	TYLASKA RD46 test sample-04	11213
D-Ring	Std. 4140 Plated Steel	7049

ANALYSIS: D-RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Tensile Test



Tylaska RD46 D-Ring

- 11,386 lbf peak load at tensile failure
- Extreme deformation with ductile failure

CWH SR-8 D-Ring

- 10,575 lbf peak load at tensile failure
- Extreme deformation with ductile failure

Standard 4140 Steel D-Ring

- Failure at low load with sudden brittle failure
- 7,049 lbf peak load at tensile failure

ANALYSIS: D-RING

Tylaska
MARINE & AEROSPACE

Failure Analysis: Results

CWH SR-8

- Ultimate failure at 10,575 lbf
- Ductile deformation provides warning before failure

Tylaska RD46

- Ultimate failures 10,949-11,386 lbf
- Ductile deformation provides warning before failure

Tylaska MARINE & AEROSPACE

Failure Analysis: Results

Standard 4140 Steel D-Ring

- Ultimate failure at only 7,049 lbf
- Brittle failure with fracture at webbing slot. Little deformation and no warning prior to failure

ANALYSIS: D-RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Fatigue Test

- High cycle repetitive loading from 0 lbf - 2000 lbf

Part type	Model	Loading	Cycles to failure
D-Ring	CWH SR-8	0 lbf-2000 lbf	17,784
D-Ring	Tylaska RD46	0 lbf-2000 lbf	36,643

Conclusion:

- In parachute riser applications, fatigue test results show that D-Ring will be intact beyond point of riser failure
- Tylaska parts exceed industry standard

ANALYSIS: D-RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Shock Load Test

Description: Identify failure mode produced by severe shock load on D-ring

- Concrete block drops and suddenly stops on rigid chain to produce severe shock loading
- 1,600 lb block drops 10 ft and comes to sudden stop while connected to D-Ring

ANALYSIS: D-RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Shock Load Test

- Tylaska D-Ring RD46
  - Highly ductile failure under shock. Displays severe deformation

- CWH D-Ring SR-8
  - Highly ductile failure under shock. Displays severe deformation

- Standard steel No.8 D-Ring
  - Brittle failure at webbing slot. Little deformation displayed at failure

D-Ring takes full impact of shock load

ANALYSIS: D-RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Tensile Test at extreme low temperature -70°F

Part type	Model	Temperature	Breaking Load (lbf)
D-Ring	Tylaska RD46	-70°F	14,270

- Result: Ductile failure comparable to normal room temperature test.
- Breaking strength increases at low temperatures
- Conclusion: Suitable for use at extreme altitudes

ANALYSIS: D-RING

Tylaska MARINE & AEROSPACE

Inspection: Surface Hardness

- Surface hardness is an indicator of material strengthening
- Example of impressions left from hardness tests

Part type	Model	Surface Hardness
D-Ring	CWH SR-8	99-103 Rockwell B
D-Ring	Tylaska RD46	98-103 Rockwell B
D-Ring	4140 Steel	40 Rockwell C (hardened by Heat Treatment)

ANALYSIS: D-RING

Tylaska MARINE & AEROSPACE

Inspection: Surface Finishing

- Rings must be free of burrs and sharp edges in order to be safe for use with webbing products
- Inspection of critical areas in slot interior
- Smooth, polished surface prevents abrasion and corrosion

OVERVIEW: MIDDLE RING

Tylaska MARINE & AEROSPACE

Analysis of common Middle Rings

- Standard 4140 Steel
- CWH 5009
- Tylaska R30

Tests

- Proof load & tensile test
- Fatigue test
- Low temp. Tensile test

OVERVIEW: MIDDLE RING

Tylaska MARINE & AEROSPACE

Dimensions of Common Middle Rings

Part Type	Raw material	Part no.	Manufacturer	Thickness (mm)	Outside diam. (mm)	Inside diam. (mm)
Stainless Steel Middle Ring	316L Stainless Steel	R30	Tylaska	5	30	20
Stainless Steel Middle Ring	316L Stainless Steel	SR-5009	CWH	5	30	20
4140 Steel Middle Ring	4140 Steel	No. 3	Various	5	31.6	21.9

ANALYSIS: MIDDLE RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Tensile Test

CWH 5009

Tylaska R30

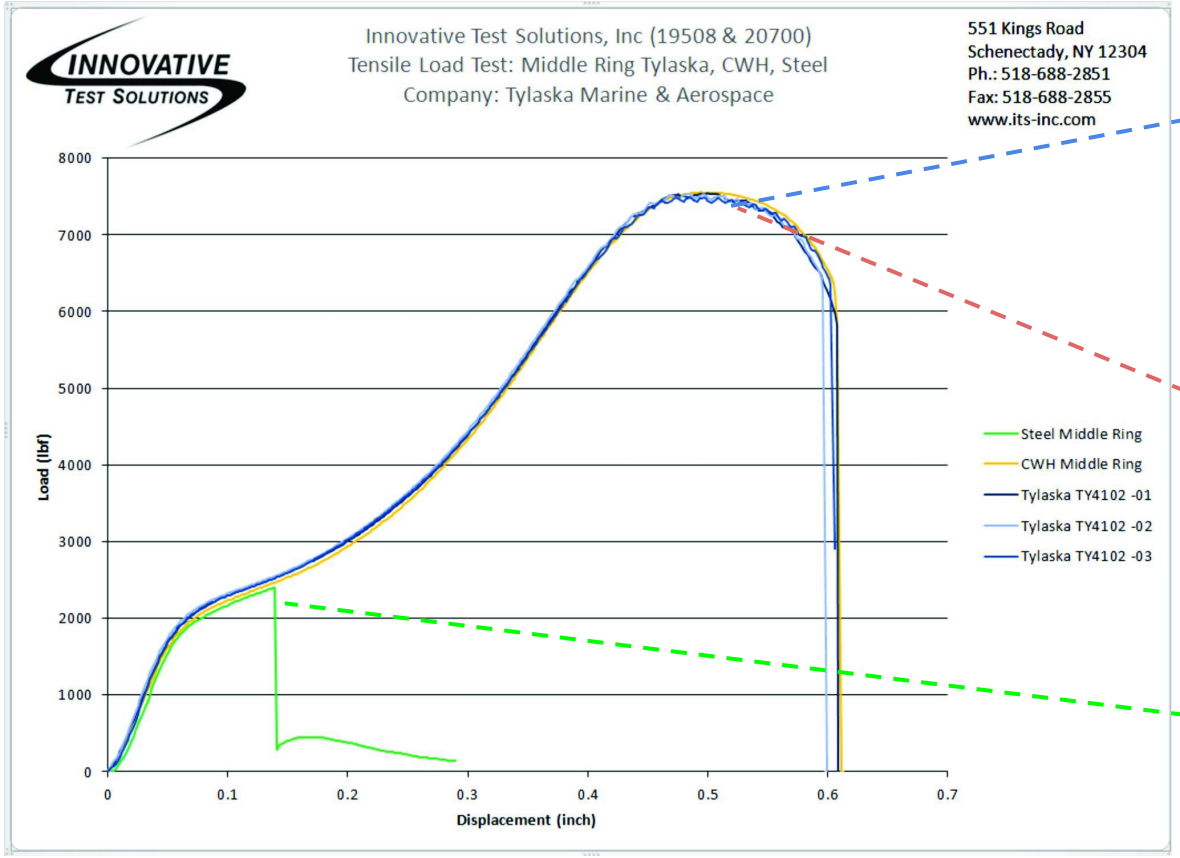
Std. Steel Middle Ring

Type	Sample	Breaking Load (lbf)	Observations
Middle Ring	CWH 5009	7555	Ductile failure
Middle Ring	Tylaska R30 -01	7540	Ductile failure
Middle Ring	Tylaska R30 -02	7533	Ductile failure
Middle Ring	Tylaska R30 -03	7488	Ductile failure
Middle Ring	Std. Steel ring	2397	Brittle failure

ANALYSIS: MIDDLE RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Tensile Test



Tylaska R30 Middle Ring

- 7,540 lbf peak load at tensile failure
- Extreme deformation with ductile failure

CWH 5009 Middle Ring

- 7,555 lbf peak load at tensile failure
- Extreme deformation with ductile failure

Standard 4140 Steel Middle Ring

- 2,397 lbf peak load at tensile failure
- Low tensile failure at ⅓ load of cold forged parts
- Little deformation warning before brittle failure

ANALYSIS: MIDDLE RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Fatigue Test

Tylaska R30

CWH 5009

Conclusion:

- In parachute riser applications, fatigue test results show that middle ring will be intact well beyond point of riser failure
- Tylaska parts meet industry standard

Part type	Model	Loading	Cycles to failure
Middle Ring	CWH 5009	0 lbf-1100 lbf	24,070
Middle Ring	CWH 5009	0 lbf-1100 lbf	28,472
Middle Ring	Tylaska R30	0 lbf-1100 lbf	22,267
Middle Ring	Tylaska R30	0 lbf-1100 lbf	25,350

ANALYSIS: MIDDLE RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Tensile Test at extreme low temperature -70°F

- Sample: Tylaska 316L R30 Middle Ring
- Result: Ductile failure comparable to normal room temperature test.
- Breaking strength increases from 7,500 lbf to 8,640 lbf.
- Conclusion: Suitable for use at extreme altitudes

Part type	Model	Temperature (°F)	Breaking Load (lbf)
Middle Ring	Tylaska R30	-70°F	8,640

OVERVIEW: SMALL RING

Tylaska MARINE & AEROSPACE

Analysis of common Small Rings

- Standard 4140 Steel
- CWH SR-4
- Tylaska R19

Tests

- Proof load & tensile test
- Fatigue test

SMALL RING: DIMENSIONS

Tylaska MARINE & AEROSPACE

Dimensions of Common Small Rings

Part Type	Raw material	Part no.	Mfg.	Thickness (mm)	Outside diam. (mm)	Inside diam. (mm)
Small Ring	316L stainless steel	R19	Tylaska	3	19	13
Small Ring	316L stainless steel	SR-4	CWH	3	19	13
Small Ring	4140 Steel	No. 4	Various	3	20.3*	14

*Note: Steel small ring 20.3mm OD is <u>not</u> compatible with Stainless Middle Rings' 20mm ID! These parts will not assemble and are not compatible.

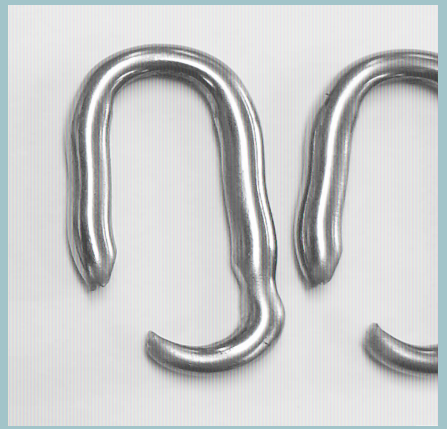
ANALYSIS: SMALL RING

Tylaska MARINE & AEROSPACE

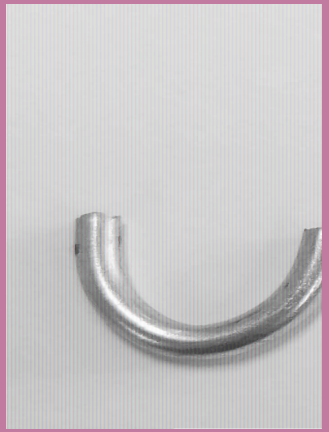
Failure Analysis: Tensile Test

CWH SR-4

Tylaska R19



4140 Steel

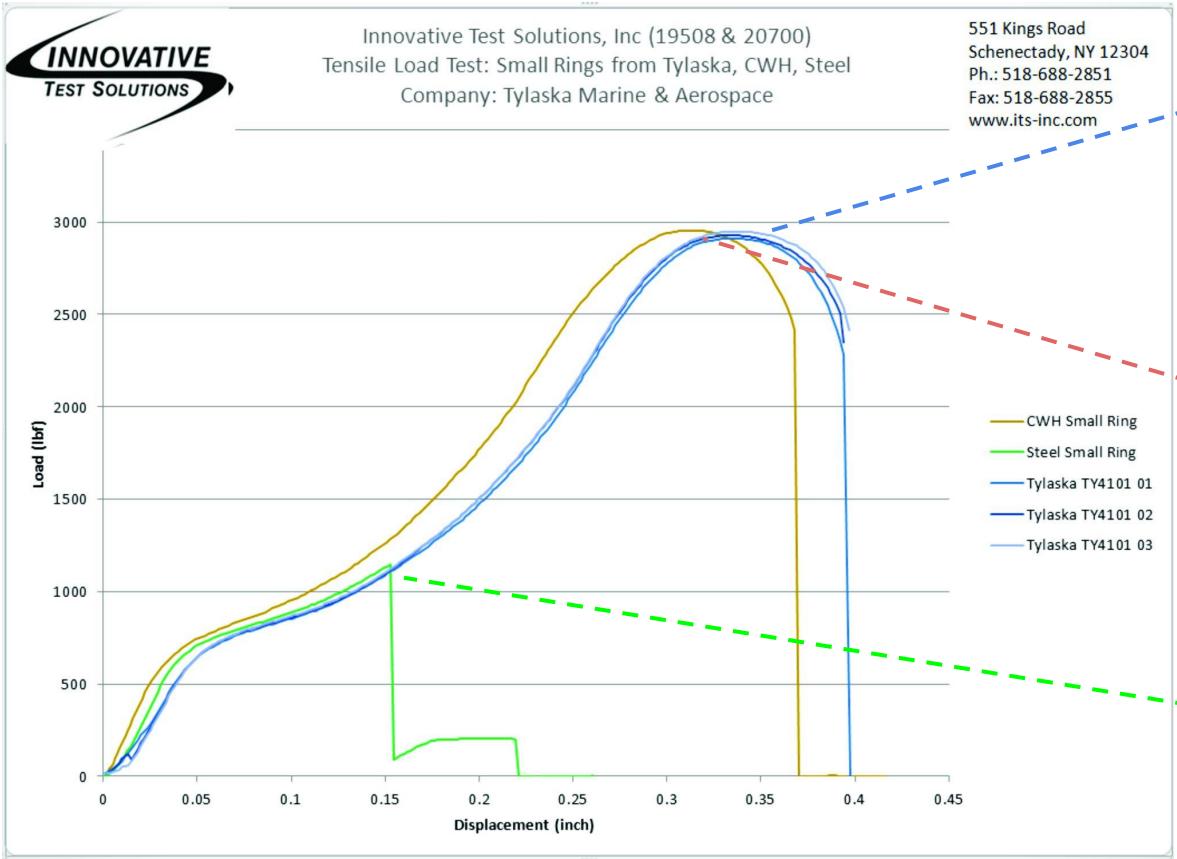


Type	Sample	Breaking Load (lbf)
Small Ring	CWH SR-4	2956
Small Ring	Tylaska R19 -01	2911
Small Ring	Tylaska R19 -02	2928
Small Ring	Tylaska R19 -03	2950
Small Ring	Standard 4140 Steel No.4	1154

ANALYSIS: SMALL RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Tensile Test



Tylaska R19 Small Ring

- 2,950 lbf peak load at tensile failure
- Extreme deformation with ductile failure

CWH No.4 Small Ring

- 2,956 lbf peak load at tensile failure
- Extreme deformation with ductile failure

Standard 4140 Steel Small Ring

- 1,154 lbf peak load at tensile failure
- Low tensile failure at less than ½ the load of cold forged parts
- Little deformation warning before brittle failure

ANALYSIS: SMALL RING

Tylaska MARINE & AEROSPACE

Failure Analysis: Fatigue Tests

Tylaska R19

CWH SR-4

Conclusion:

- In parachute riser applications, fatigue tests show that small ring will remain intact beyond the point of riser failure
- Tylaska parts exceed industry standard

Part type	Model	Loading	Cycles to failure
Small Ring	CWH SR-4	20 lbf-500 lbf	18,053
Small Ring	CWH SR-4	20 lbf-500 lbf	18,147
Small Ring	CWH SR-4	20 lbf-500 lbf	13,547
Small Ring	Tylaska R19	20 lbf-500 lbf	50,392
Small Ring	Tylaska R19	20 lbf-500 lbf	28,571
Small Ring	Tylaska R19	20 lbf-500 lbf	31,449
Small Ring	Tylaska R19	20 lbf-500 lbf	44,373
Small Ring	Tylaska R19	20 lbf-500 lbf	40,807

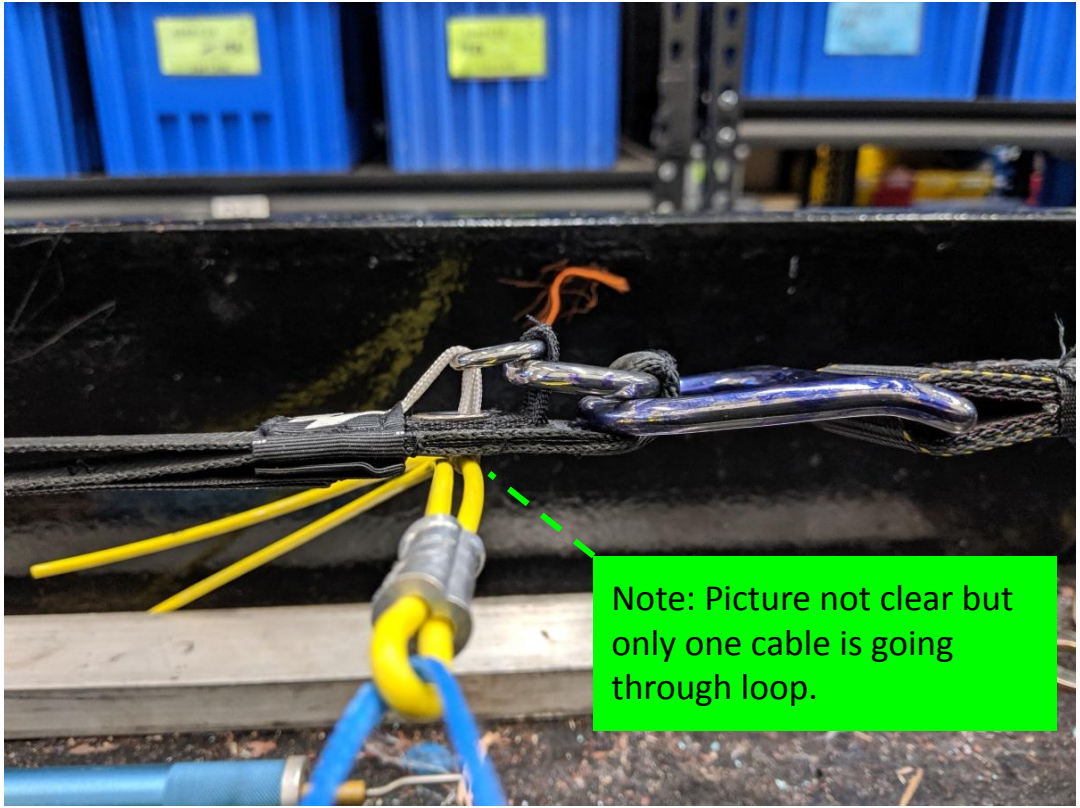
ANALYSIS: RISER TESTING

Tylaska MARINE & AEROSPACE

3-Ring Assembly with Riser Testing

Riser tests to be discussed

- Tensile test
- Fatigue test
- Shock load test
- Mechanical advantage
- Ground-level cut-aways
- Live skydive cut-away



ANALYSIS: RISER TESTING

Tylaska MARINE & AEROSPACE

Failure Analysis: Riser tensile test

Conclusion

- Riser fails above 4000 lbf without deformation of the rings
- Note: Impressions visible on D-Ring can be used to identify extreme overloading of riser

Part type	Components	Configuration	Breaking load (lbf)
Type 17 Mini 3-Ring Riser	CWH SR-4, SR-5009, CWH SR-8	Tensile break test	4192
Type 17 Mini 3-Ring Riser	Tylaska R19, R30, RD46	Tensile break test	4080
Type 8 3-Ring Riser	Tylaska R19, R30, RD46	Tensile break test	4410

Tylaska MARINE & AEROSPACE

Failure Analysis: Riser with 3-Ring Fatigue Test

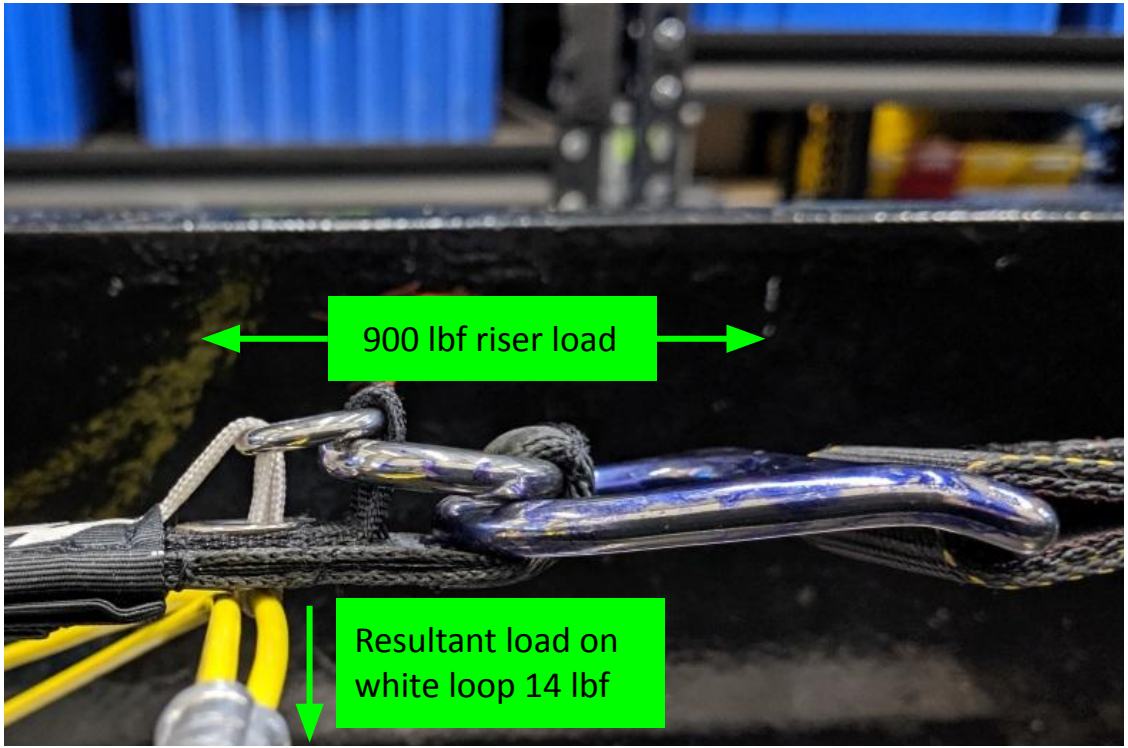
- High cycle loading at 725 lbf with D-Ring connection
- Failure mode: riser failure at stitching on front side loop.
- Conclusion: Fatigue test shows that forgings are intact after point of riser failure

Part type	Components	Fatigue Loading	Fatigue life
Type 17 Mini 3-Ring Riser	Tylaska R19, R30, RD46 rings	0 lbf to 725 lbf	11,697 cycles

Tylaska MARINE & AEROSPACE

Analysis: Mechanical Advantage of a typical 3-Ring Assembly

- Type 17 riser assembled with 3-Rings
- 3-ring mechanical advantage measures approximately 64:1 at high loads
- 900 lbf riser loading places is 14 lb tension on white loop

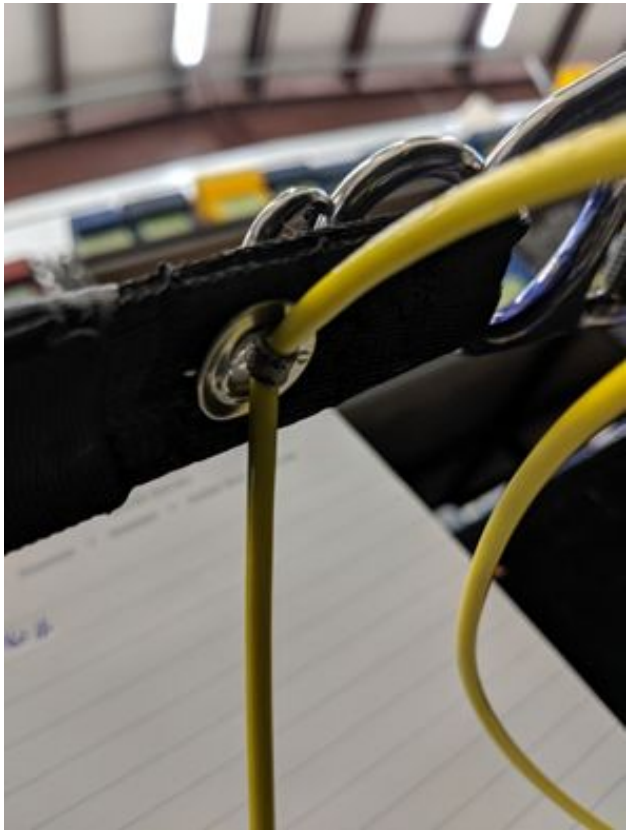


LIVE TESTING OF TYLASKA 3-RING

Tylaska MARINE & AEROSPACE

Analysis: Cut-away operation under high riser tension

- Cut-away function successfully tested at 1,000 lbf riser loading
  - Immediate release



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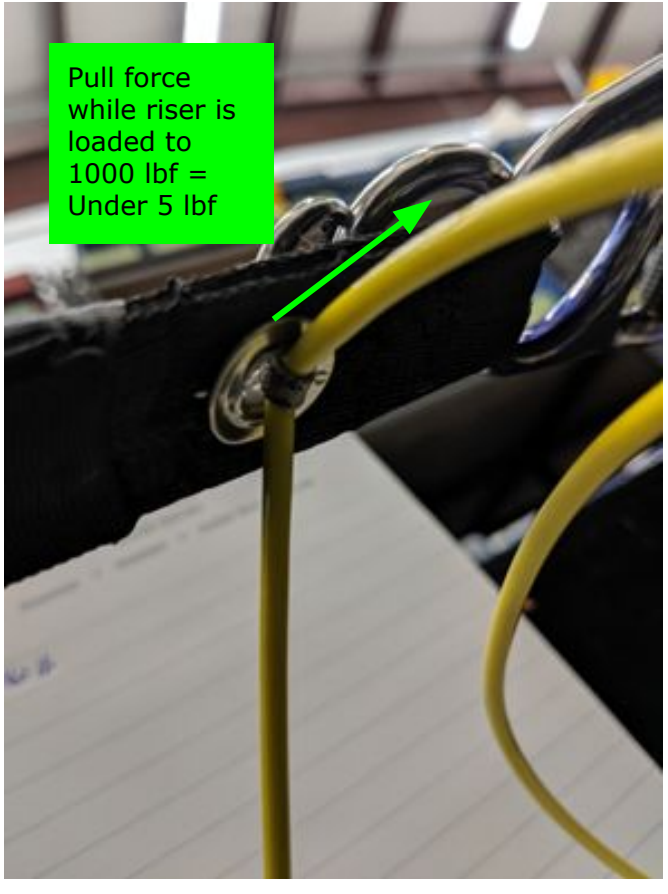
Analysis: Cutaway function under high riser tension

- Note: At 1000 lbf riser loading, pull force required to slide single yellow cord under white loop is under 5 lbf

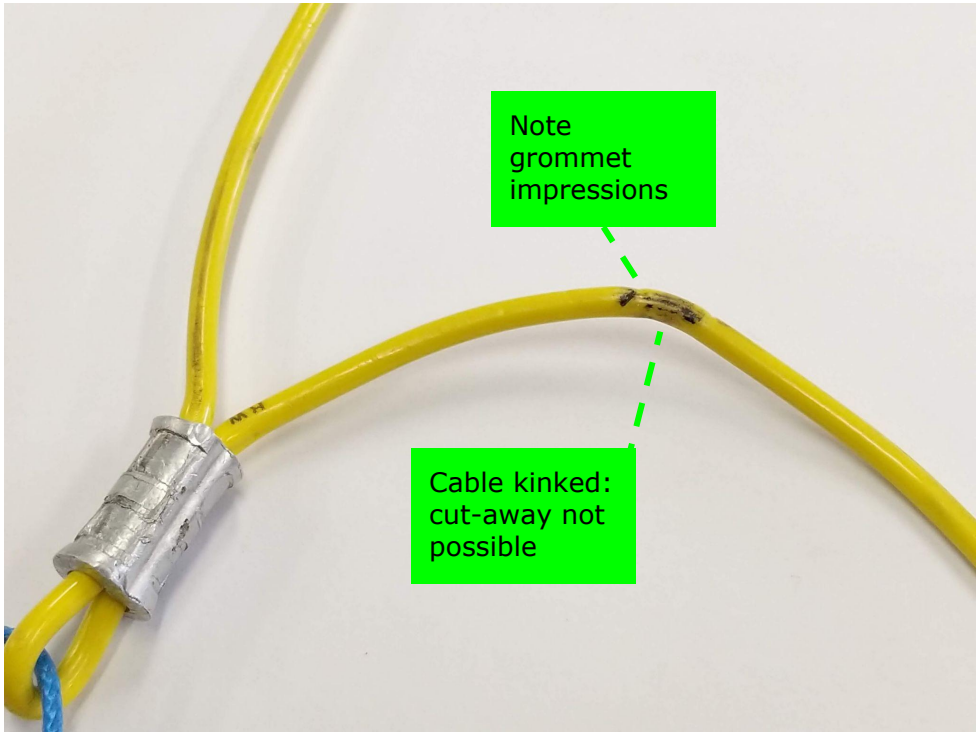


LIVE TESTING OF TYLASKA 3-RING

Tylaska MARINE & AEROSPACE

Cutaway function of typical mini 3-Ring system fails above 1500 lb riser loading

- Note: At high riser loads of approximately 1,500 lbf, yellow cable becomes indented by grommet: Cutaway cable will be extremely difficult to pull.
- At extreme riser loading of approximately 3,000 lbf, the cable becomes kinked and entirely seized from movement. Cut-away would not be possible in this condition



Tylaska MARINE & AEROSPACE

Live Testing: Hanging harness cut-aways

- Cutaway tests in hanging harness

Normal 3-Ring Assembly

3-Ring Assembly at time of cutaway release

Riser released from main container D-Ring

Tylaska MARINE & AEROSPACE

Live Testing: Hanging harness cut-aways

- Cut-away tests at low level

LIVE TESTING OF TYLASKA 3-RING

Tylaska MARINE & AEROSPACE

Live Testing: Skydive cut-away

- Live cutaway test using Tylaska 3-Ring on a custom cut-away test jump rig
- Skydive cut-away
  - 6,000’ AGL main release with RSL and MARD (Main Assist Reserve Deployment)
  - Immediate reserve opening by MARD
- Result: Successful cut-away done by Tim Tylaska of Tylaska Marine and Aerospace

LIVE TESTING OF TYLASKA 3-RING

Tylaska MARINE & AEROSPACE

Live Testing: Skydive cut-away

Skydive Cutaway Video

Tylaska MARINE & AEROSPACE

3-Ring Testing and Analysis: Conclusion

- Tylaska has thoroughly analyzed the performance of the individual 3 ring components and performance as an assembly.

- These test results give Tylaska the confidence to certify its manufactured rings:
  - Safe for use in parachute container risers
  - Meet or exceed industry standard for stainless steel hardware

THE END

THANK YOU!

- Thank you for taking part in our presentation!
- We are interested in your questions, comments, and feedback.
- Let’s go skydiving

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