

Rope to Chain Splice Test

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June, 1994

Background

Anchor rodes have traditionally been made from either nylon line, galvanized chain, or a combination of the two materials. The chain's weight and abrasion resistance make it appropriate for the abrasive conditions on the sea bed, while the nylon's elasticity and light weight provide desirable properties for the majority of the rode. Since each material has advantages and disadvantages, boaters frequently use a short length of chain (a boat length is a popular choice) at the anchor end, and a much longer length of nylon line at the boat end.

When anchors and rodes exceed the weight that a person can comfortably lift by hand, windlasses are used to either increase the pulling power of the crewmember, or to use electric motors to do the work of weighing anchor. When rodes are made entirely from chain, windlass operation is straight forward, since the chain is self-tailing and self-stowing in most installations. When rodes are made entirely of rope, windlasses are available that will reliably pull the line and deposit it below decks. It is when combination rodes are used that problems can arise.

This is due to the connection between the chain and rope. In most cases, this is accomplished using an eye splice around a thimble on the line, and a galvanized anchor shackle. This arrangement is strong and protects the line from chafe where it joins the anchor chain. Unfortunately, it is difficult to pull using an anchor windlass, since the thimble/shackle cannot be pulled using the capstan or gypsy of the windlass. In most cases, the anchor rode will have to be temporarily made fast while the anchor rode is moved from the capstan to the gypsy. This can be hazardous, and overrides are common.

The other problem is that it is difficult to pass an eye and thimble below decks, unless a large chain pipe is used. It is virtually impossible to construct a self-tailing/self-stowing windlass system when using a thimble and shackle.

For many years, Simpson Lawrence has offered a patented gypsy with a set of angled grooves in the center of it, allowing it to pull both 1/2" and 5/8" nylon line, and 5/16" chain. To connect the chain to the line, Simpson Lawrence recommends a rope to chain splice, consisting of a relatively common eye splice through the last link of chain. The line is seized about 12" from the end, the strands are parted, and two strands are passed in one direction through the link, while one strand is passed in the other direction. The strands are then spliced using normal technique. Various tapering methods can be used, but Simpson Lawrence recommends three full tucks, then two additional tucks made with half-diameter strands. This makes a compact, rapidly tapered splice.

The apparent problems with this method are twofold:

1. There is concern that the line will wear rapidly where it contacts the limited surface area of the link of chain.
2. Lines lose strength when passed around a tight radius, since the outer strands are placed under higher tension than the inner strands, due to the different radii.

While the chafe problem is a concern, chafe is generally caused by lines rubbing against a rough surface. In the case of the rope-chain splice, there is little relative movement, since the splice will be in tension. However, the cyclical loads that occur when a boat anchors in waves or gusting winds will eventually cause localized wear at the contact point with the link of chain. While the prudent mariner will inspect all lines for chafe, and can easily shorten the line and make a new splice if chafe occurs, more testing needs to be done to see if the loading and unloading of the splice causes sufficient abrasion to be of concern during the duration of a storm.

The small radius concern, however, is easily tested, and we designed a test to quantify the reduction in strength due to the rope to chain splice.

The Test Samples

We constructed fifteen samples of line and chain, which were sent to New England Ropes in New Bedford, MA for tensile strength testing. New England Ropes has a rope testing lab which allows them to test line to destruction, measuring both stretch and strength.

A set of ten samples was constructed as follows:

1. One 5/16" galvanized anchor shackle from Landmann (SWL 1,500 lbs., ultimate strength 9,000 lbs.)
2. Two feet of 5/16" BBB chain from Acco (SWL 1,900 lbs, ultimate strength 7,600 lbs.)
3. Eight feet of 5/8" New England Ropes Caprolan nylon line (ultimate strength 12,200 lbs.). A five tuck, tapered eye splice was placed in the end of each sample, and a five tuck, tapered rope to chain splice was placed in the other end.

A second set of five samples was constructed using smaller components:

1. One 1/4" galvanized anchor shackle from Landmann (SWL 1,000 lbs., ultimate strength 6,000 lbs.)
2. Two feet of 1/4" proof coil chain from Acco (SWL 1,250 lbs, ultimate strength 5,000 lbs.)
3. Eight feet of 1/2" New England Ropes Caprolan nylon line (ultimate strength 7,500 lbs.). A five tuck, tapered eye splice was placed in the end of each sample, and a five tuck, tapered rope to chain splice was placed in the other end.

The purpose for including the anchor shackles was twofold: it provided a larger attachment point for connecting the test apparatus, and it simulated the components that would be part of a normal anchor rode. While it is common to use "one size larger" than the chain size, anchor shackles are supposed to be equal in strength to the same size BBB and proof coil chain.

New England Ropes estimates that a properly spliced eye in the end of a line sample retains 95% of the strength of the unspliced line. New England Ropes also states the breaking strength of their line assuming that a splice is in place; in other words, the 12,200 lb. claimed strength of 5/8" nylon assumes that a splice is part of the assembly. Thus, the line was the strongest component in both sizes of assemblies.

Sample # 6 was constructed with some additional chafe protection on the inside of the link of chain consisting of several layers of polyurethane self-amalgamating tape. This caused the line to be spliced differently than the other samples, since all three strands had to pass through from one side to the other. Sample #4 was made with five full tucks and five tapered tucks. This was an attempt to see if the severity of the taper would affect the strength.

Our 1/2" samples consisted of two styles: #11-13 were the Simpson Lawrence recommended splice method, with two strands passing one direction, and one strand passing in the other direction through the chain link. #14 and 15 were spliced by passing all three strands through the link of chain, much as one would make a very small eye splice.

The Results

The samples were pulled by New England Ropes' linear screw test apparatus under Cordage Institute conditions. The Cordage Institute requires that line be pulled at 1/2" per minute for each foot of rope. As each assembly had about five feet of rope after the splices were complete, the assembly was pulled at about 2.5 inches per minute. The first two pulls were conducted with a heavy rope cover over the

assembly to serve as a guard against flying pieces. This proved unnecessary, and the cover was removed after sample #2 was tested.

With the exception of #5, the large samples, #1-10, broke where the rope wrapped around the chain link. Breaking strengths varied from 9,975 lbs. (#4, with the extra long taper) to 11,690 lbs., with an average of 10,695.9 lbs. This represents 87.7% of the claimed strength of the line. After tensioning, all anchor shackle pins were bent, shackle bodies were elongated, and the chain was stretched so that some links would no longer move relative to one another. This indicates that each assembly was close to the failure point of other components.

#5 broke the anchor shackle at a tension of 10,560 lbs.

With the exception of #15, the small samples, #11-14, broke where the line wrapped around the link of chain. Breaking strengths varied from 5,240 lbs. (#1) to 6,400 lbs. (#5), with an average of 5,937 lbs. This represents 79.2% of the rope breaking strength. It is not clear why this size lost more of its strength than the larger samples, although the small cross section of the 1/4" chain links appears to offer much less contact area for the line. The two "regular" splices fared better than the "two strand/one strand" versions. #14 and #15 broke at an average of 85% of the line strength, while #11-13 broke at 75.3%.

As with the larger samples, the chain links were stretched as much as 17% over their nominal inside dimensions, indicating that they were close to failure. Some of the welds in the chain showed signs of cracking, and all were visibly distorted in length.

Conclusions

1. The chain used in this test is conservatively rated, and withstood loads at least 5-50% above its stated ultimate strength. The shackles also exceeded their ultimate strength ratings by 10-30%. Both products have a high ratio of ultimate strength to working load limit.
2. The small radius of the rope to chain splice reduced the ultimate strength of the line by about 12% in the case of 5/8" line, and 25% in the case of 1/2" line. This value is comparable to the strength of conventional (non-Caprolan) 5/8" three strand nylon (10,400 lbs.) and conventional 1/2" three strand nylon line (5,750 lbs.)
3. If the chain splice is examined for chafe on a regular basis, we find no objections to the rope to chain splice from a strength reduction standpoint, as it appears close in strength to other components in the system and to commonly available nylon line.
4. Having established a baseline for one type of splice, more testing should be done with alternative splices, including those with no taper, less taper, fewer tucks, and other variations.
5. A test should be devised that tests similar splices under cyclical loads that one might experience during a sustained storm.