AN ASSESMENT OF THE STRENGTH OF SEIZINGS AND WHIPPINGS USED TO CREATE EYE TERMINATIONS ON SAILING ROPE

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1.0 Abstract

The purpose of this project was to investigate different methods of creating an eye termination in sailing rope. The most common methods of creating eye terminations in ropes are by knots, splices, seizings and whippings. There is a lot of information on knots and splices, however there is little on the seizing and whipping methods. It was decided to focus this project on the seizing and whipping methods.

Initial tests were then carried out on various whippings and seizings to determine their strength. The initial results indicated that the seizing method was far superior to the whipping method. On this basis due to the limited strength of the whippings it was decided not to investigate whippings any further.

The rest of the project focused on the seizing method and the variables that altered the strength. It was concluded that the number of stitches and the length of stitching influence the strength of the efficiency most notably. This project showed that seizing's can have similar strengths to knots.

2.0 Nomenclature

$\sum$ = Sum

% = percentage

cm = centimetres

lbs = pounds force

m = metres

M15 = Laboratory room

mm = millimetres

n = number of samples

s = standard deviation

$\bar{x}$ = sample mean

x_i = sample value

3.0 Introduction

The topics of different types of knots and splices used in the sailing environment have long been the subject of interest. Specifically the area of particular interest for this project is that of the sailing rope used to control the sail itself. Due to this, different methods of attaching rope to another rope, fixed point or sail are required. One way of attaching rope is to create an eye termination the most common methods for creating an eye termination are, by forming a knot, splicing or seizing. A seizing is where the end of the rope is stitched to the standing part of the rope using binding twine. The main objective of this project is to discover the strength of different types of seizing's and what factors contribute to the strength.

There is already sufficient data on knots in sailing ropes and splices from previous work and projects **[1, 2]**. Unlike splices or knots there is very little information published on the formations of seizing's or their specific strength **[3, 4]**. As there is little information available in how to create the seizing to achieve optimum strength or efficiency assumptions were based off initial tests. This project has attempted to find the most efficient method for creating the seizing, as well as analysing the effects on the seizing by changing several different variables.

The seizing's created during this experimented were applied to 12mm braid on braid polyester sailing rope. This was the only type of rope used in the experiments throughout this project.

Another way of constructing an eye termination called *whipping* **[3, 4]**, which is similar to a seizing, creates an eye termination by binding the end of the rope to the standing end of the rope using binding twine. This method did not involve stitching through the rope at all. This method was tested but it became apparent that this method had several limitations and proved very weak compare to the seizings.

To ensure non-biased and accurate results, certain variables were kept constant throughout the testing of the seizings. The variables that were kept constant are;

- 12mm polyester braid on braid rope
- Same size needle of 60cm length
- The same type of binding twine

The variables which were altered to analyse the performance of the seizings were;

- The type of stitching
- The number of stitches per unit length
- The length of stitching along the rope
- The size of the eye termination
- The manufacturer

It should be noted that when one variable was altered the rest were kept constant in order to analyse the individual effect of the variable being altered on the seizing's performance. The efficiency of each seizing was then calculated in excel using equation 1.1.

$$Seizing/Whipping \cdots Efficiency = \frac{Failure \ldots Load \ldots of \ldots seizing/whipping}{Failure \ldots Load \ldots of \ldots rope}$$

Equation (1.1)

A testing technique was developed to measure the failure load of the seizings constructed for this project. The same testing procedure was then carried out and applied to every seizing constructed for testing. The failure load of each test was then recorded into the lab book. The data recorded was then inputted into excel to calculate the efficiency for each seizing.

4.0 Procedures

Several different procedures were carried out before the main body of testing was carried out for this project. The first step of the proceedings was to carry out research before any experimental procedures and tests were conceived. Once the research was completed to gain any previous information on eye terminations **[1, 2]**, the main focus of this project and its objectives were decided.

A testing method and procedure then had to be derived in order to test the various whippings and seizings. The test specimens could then be conceived and constructed for testing once the testing procedure was decided.

Firstly initial tests were conceived to determine the strength of the various different seizings and whippings. From the results of these tests a seizing construction was then chosen to analyse in more detail for the remainder of this project.

A datum seizing was also established from these results so that when one variable was altered all other variables remained constant **[5, 6]**. This ensured a fair experiment and an accurate depiction of the effect of the variable altered on the seizing's efficiency.

4.1 Testing procedures

The first test to be carried out before any whippings or seizings were tested was the actual strength of the rope. This test was very important as the result was then used in all calculations to work out the efficiency for each individual seizing. The machine used for the testing procedures was a Tinius Olsen tensile testing machine.

Testing of rope strength

To test the rope strength the following procedures were carried out. Firstly two meters of 12mm braid on braid polyester was cut using a hot knife. The test was then carried out on the tension and compression machine as illustrated in figure 1.

Figure 1

The rope was then secured by tying a knot at either end after it was wrapped round the drums twice at either end. The rope was then clamped between two metal plates by bolting the plates together with the rope in between to secure the rope. Once the rope was secured between the two drums on the testing machine the test was carried out. The test essentially involves subjecting the rope to a tensile load until failure occurs. The instant the rope failed was then recorded on an analogue gauge, attached to the Tinius Olsen machine that recorded the failure load to the nearest 10lbs. The scale on the Tinius Olsen machine used for all the tests was a maximum of 10,000lbs with 10lb increments on the scale. Once failure occurred the testing was stopped and the failure load of the rope recorded in a lab book.

Testing procedure of Seizings and Whippings

The same experimental methods and procedures are used to test the seizings and whippings bar one difference. The only difference between the rope test and the whipping and seizing tests is in the set up of the machinery. Instead of a drum being attached to the bottom part of the machine, a different attachment was used in the form of a shackle. This set up is illustrated in figure 2.

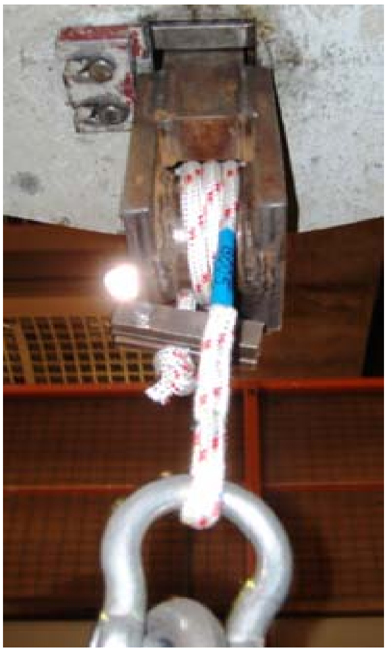

Figure 2

The test specimen consisted of a 1.3m length of 12mm braided rope which had a seizing or whipping formed at one end. The standing end of the rope was attached to the top part of the machine as before. The seizing was then attached using the shackle to the bottom platform.

This procedure was then carried out for every other seizing and whipping manufactured to ensure a fair experiment and that there were no discrepancies in the results due to a difference in testing procedure.

4.2 Processing the Results

Once all the data collected in the lab had been recorded into the lab book and inserted into excel various equations and graphs were used to analyse the data collected. Several different spreadsheets were formed in order to analyse the different types of seizings. For the main body of results three separate tests were carried out on each different type of seizing. This was in order to achieve an accurate representation of the efficiency of each different type of seizing manufactured. As three results were obtained for each type of seizing it was then possible to calculate the error involved. The efficiency for each seizing was calculated by inputting equation 1.1 into excel. After each of the efficiencies were calculated for all the seizing's, the mean (average) efficiency, median efficiency and the standard deviation was calculated from each of the three tests for the different types of seizings. The equations used to calculate the standard deviation and mean are shown in **appendix A**.

5.0 Results from Testing

For the rest of this project it was decided to analyse the seizing method in more detail. In order to do this, different variables were altered and there effects on the efficiency recorded. Although the manufacturer published a breaking load for the rope, the rope was tested to find its actual strength and give a more accurate representation of the seizing efficiencies. The failure load of this rope is given below along with the manufacturer's rated value.

Tested Rope failure load = 5200lbs

Manufacturer's rated value = 6380lbs **[7]**

Results of different stitching methods

The next set of tests focuses on the different stitching methods used in creating the seizings. This was carried out to obtain the most effective method of stitching that yielded the most efficient seizings. Three different types of stitching were applied and different variables were altered for each. For each type and variable altered three different tests were carried out on each to give an average and obtain an error for each stitching type. An illustration of the final seizing choice that was manufactured from the initial results is shown below in figure 3.

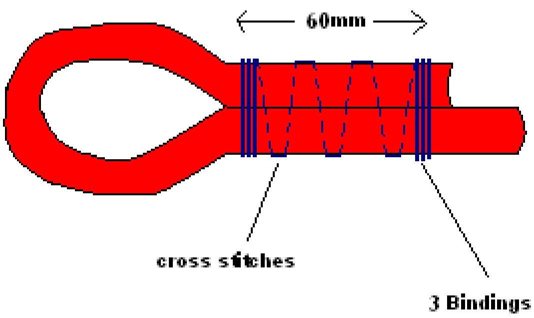

Figure 3

From the seizing in figure 3 the following datum values were used and applied to all other seizings;

- *Eye termination length = 14cm*
- *Stitching/whipping length = 6cm*

Table 1.1 gives the information from the most efficient stitching type obtained from the results. This stitching type was then applied as a datum for the remaining tests involving the seizings.

Seizing data set	Average (mean) % efficiency	% Standard Deviation
S025 to S030	**48.0**	**1.83**

Table 1.1

The other variables applied in the final seizing choice were as follows;

24 stitches along the 6cm datum length i.e. 4stitches/cm

Two lengths of binding twine used to complete the stitching.

Throughout the process of testing the different types of stitching gradually the least favourable variables were discovered and discarded from further testing. A graph of all the different seizings and their respective altered variables is illustrated in figure 4.

Figure 4

Graph of different stitching methods and their respective efficiencies

Different colours represent the three different stitching types; the alterations in position are with the changing variables applied to each stitching method.

An illustration of the final, most efficient stitching method used for the rest of the testing is shown below in Figure 5**.**

Figure 5

Results of seizing's created by different manufacturers

The final seizing choice decided from the previous section was then used to test seizing's created by different manufacturers. This was carried out in order to determine whether the seizings created by different manufacturers yielded different efficiencies. In order to carry out this test firstly a set of instructions were written and distributed to different users to manufacture the seizings. Three different manufacturers created three seizings each; these were then tested and compared to the user's results. The results from the testing of the seizing's created by different manufacturers are shown in table 1.2.

Manufacturer	Seizing data set	Average % Efficiency	Standard deviation
User (Author)	S025 to S030 (from table 5.8)	48.0	1.83
Subject 1	M001 to M003	47.8	3.50
Subject 2	M004 to M006	50.0	4.30
Subject 3	M007 to M009	48.1	3.62

Table 1.2

From table 1.2 a graph, shown in figure 6, was created to highlight and any differences between manufacturers.

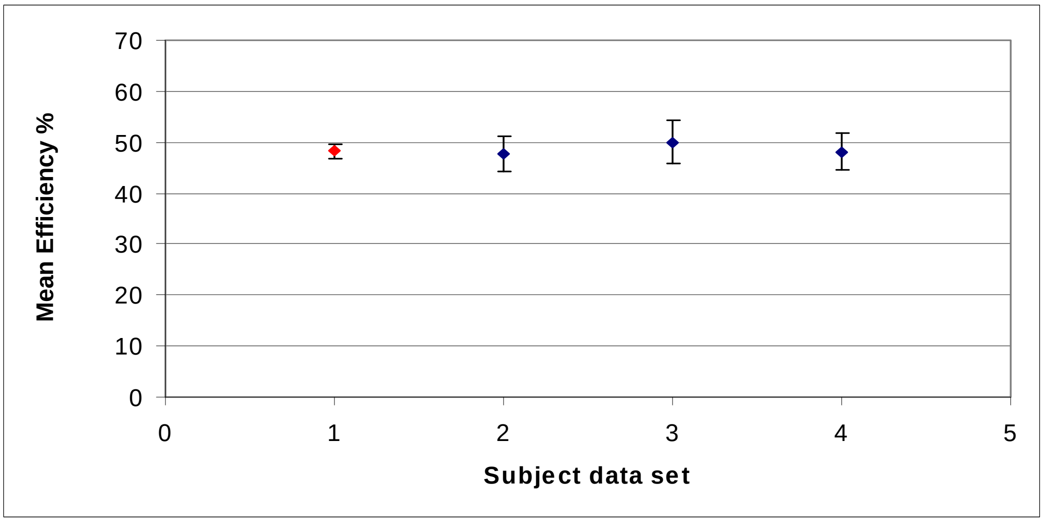

Figure 6

Seizing efficiencies from different manufacturers

As illustrated by the graph there is little difference between the results obtained from the different manufacturers. It should be mentioned that some of the manufacturers had no previous knowledge of constructing seizings while others did; the results indicate that this is not a significant factor.

Results of Seizing Efficiency from altering stitching length

The next variable to be altered was the length over which the rope was stitched. With all previous experiments this length was kept constant at 6cm. The stitching density remained constant at 4 stitches per centimetre whilst the length over which the rope was stitched was varied. The various lengths tested and their corresponding efficiencies are shown in table 1.3.

Stitching length (cm)	Seizing data set	Average % Efficiency	Standard deviation
4 (16 stitches)	L011 to L012	**39.4**	**2.14**
6 (24 stitches)	S025 to S030	**48.0**	**1.83**
8 (32 stitches)	L001 to L003	**51.1**	**1.54**
10 (40 stitches)	L004 to L006	**63.3**	**6.26**
12 (48 stitches)	L007 to L009	**59.9**	**7.12**
14 (56 stitches)	L013 to L015	**68.8**	**3.72**

Table 1.3

A graph of stitching length against efficiency was then plotted, shown in figure 7.

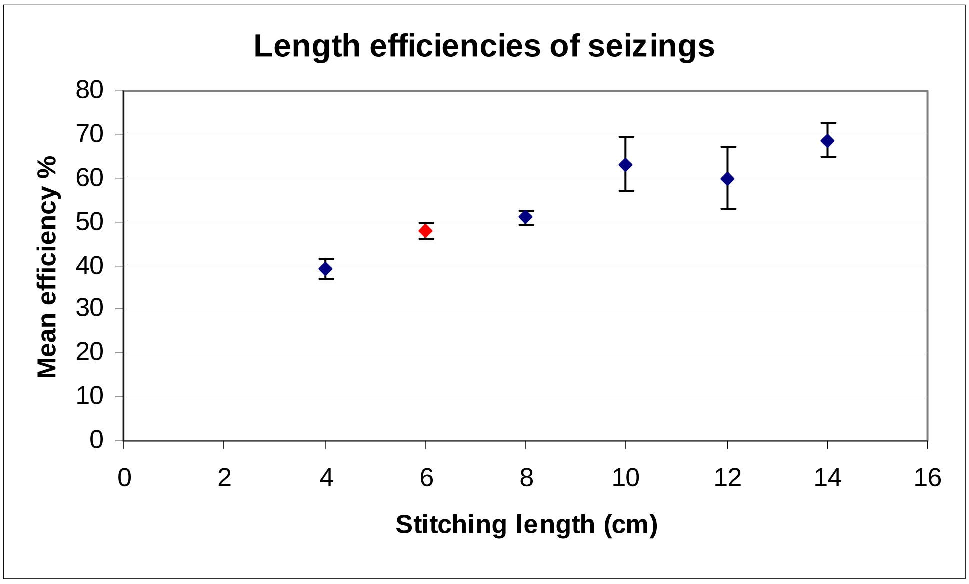

Figure 7

Stitching length compared to the seizing efficiency

As illustrated by the graph in figure 7 increasing the stitching length of the stitching clearly increases the efficiency of the seizing.

Results of Seizing Efficiency from altering eye termination size

The final variable that was altered in order to establish whether it affects the seizing efficiency was the size or length of the eye termination. Several different eye termination lengths were altered and tested. The results for the efficiencies of each different eye length are shown in table 1.4.

Eye termination length (cm)	Seizing data set	Average % Efficiency	Standard deviation
10	E001 to E003	**46.5**	**3.32**
14	S025 to S030	**48.0**	**1.83**
16	E004 to E006	**45.6**	**1.97**
22	E007 to E009	**45.7**	**1.66**
30	E010 to E012	**43.1**	**1.91**

Table 1.4

The results are plotted in graph to illustrate the eye termination length against seizing efficiency in figure 8.

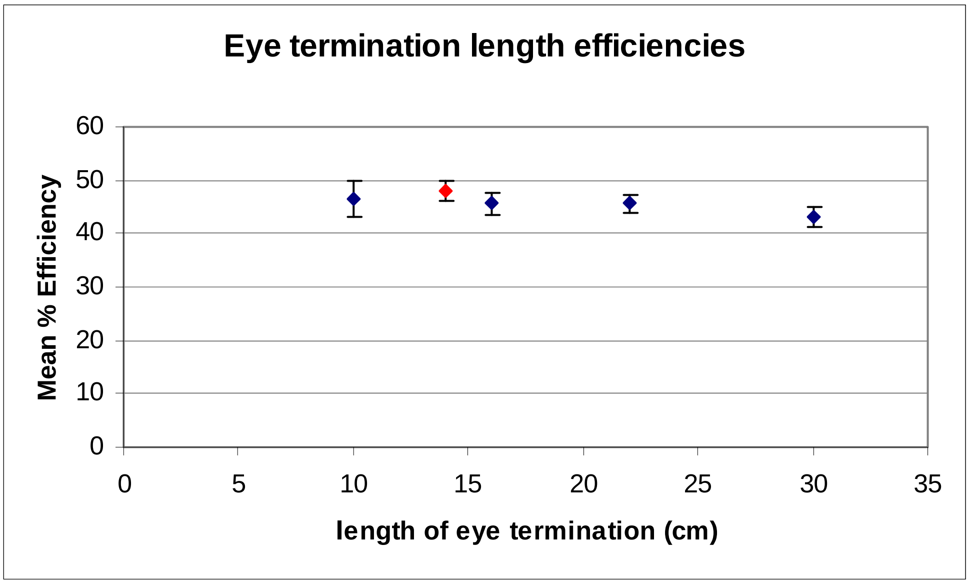

Figure 8

Length of eye termination against seizing efficiency

From the graph it is clear that altering the eye size of the diameter had very little effect on the seizing efficiencies. From the results we can obtain that increasing the eye size may very slightly decrease the efficiency of the seizing.

Summary of Results

The alteration of the variables on the seizings so far yielded some definitive results and conclusions. It was clear that the alteration of all the variables mentioned previously, each affected the results in some way. The values given in red in the tables were from the results of the datum stitching and variables decided. It was concluded that the stitching length and number of stitches per centimetre applied to the seizing altered the efficiency of the seizings most notably. The other variables altered the efficiency but only very slightly. Taking all the results into account a final seizing was manufactured with the most favourable dimensions of the altered variables applied. However, in keeping with the objectives of this project the final seizings were also manufactured for practicality and favourable size.

Final Seizing Choice

Taking into account the results so far the following seizing dimensions were applied and altered from the original datum seizing to manufacture the final seizing choice.

Number of stitches per centimetre = 4

Number of lengths of binding twine used in stitching = 2

Stitching length = 10

Eye termination length = 10

This seizing was then tested and the results are shown in table 1.5

Seizing data set	Average (mean) % efficiency	% Standard Deviation
F001 to F003	57.5	6.12

Table 1.5

From the final set of results we can obtain that the average seizing efficiency was 57.5% which is comparable to that of any eye termination formed by a weak knot. It should be mentioned that the highest efficiencies obtained for some of the variables altered were not applied to this final choice seizing. This was partly due to the fact that, the final seizing choice involved the manufacture of as small as seizing as possible.

6.0 Conclusion

The assessment of the strength of eye terminations created by seizings and whippings throughout the course of this project was successfully carried out. However, not all areas of seizings and whippings were investigated thoroughly due to time and resource limitations. The emphasis of this project was on the analysis of the seizing types, which was extensively carried out.

The conclusions made from the results were made from analysis of all results and trends indicated rather than directly comparing average values. The most significant observation made was generally how much stronger the seizings proved than the whipping method tested. However, it was also obvious that several factors influence the strength of the seizing. The most notable factors that were discovered to alter the seizing’s efficiency were the number of stitches and stitching length. The other variables altered had very little effect on the seizing’s efficiency if any; therefore any further testing on these parameters was deemed to be irrelevant.

Further area’s for investigation include, expanding the current data sets on the effective variables, manufacture of seizings on different rope types, and the specific failure modes relevant to seizings. Another area considered during this process was the concept of building a testing rig to measure the forces acting on the seizings. Although there are still considerable areas to be investigated, any further work must be applied relevantly. This project has tried to provide the most important factors that affect the strength of seizings.

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[2] University of Strathclyde, "An assessment of the strength of knots and splices used as eye terminations in a sailing environment", Katherine Milne

[3] International Marine, the Splicing Handbook second edition, Barbara Merry with John Darwin

[4] Adlard Coles Nautical, "Knots in Use" third edition, Colin Jarman

[5] www.boatdesign.net

[6] www.tollesburysc.co.uk

[7] http://www.force4.co.uk/ProductDetails

Appendix A

The following equations for the standard deviation and the mean calculated for the results are shown below with the relevant terms explained.

To calculate the sum for the data sets the following equation was used;

$$\bar{X} = \frac{\sum X}{n}$$

N = number of samples
$\sum$ = sum of the number of samples
X = value associated with each sample
$\overline{X}$ = numerical average value of samples

The standard deviation is calculated using the following equation;

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}\,,$$

Where the same symbols as used before have the same meaning

S = standard deviation

$\overline{x}$ = sample mean for each type of seizing or whipping type tested

x_i = sample value for each individual test carried out in that specific data set

i = 1, the first of the values in the series of samples up to the last sample defined as N

The standard deviation was calculated for each different seizing types constructed, where multiple tests were carried out to obtain the average and error.