Sea Quester Farms Tension Data Analysis

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1. INTRODUCTION

Sea Quester Farms cultivates kelp near Juneau, Alaska. As part of their effort to maximize efficiency and improve the work environment, Sea Quester Farms partnered with the UAF Bristol Bay Campus and the Alaska Center for Energy and Power to develop an electric kelp hauling system to replace their existing hydraulic system. The existing system requires running a diesel engine continuously for a small intermittent load, which uses fuel inefficiently and creates a loud work environment.

2. METHODS

The first step in designing an electric hauler required measuring the tension in the kelp line as it is hauled on board. To do so, Sea Quester Farms attached a smartlink^2 Cyclops Nano sensor into their hauling system. The sensor measured five variables; time, latitude, longitude, heading, and the weight imposed on it as kelp was harvested. The sensor was set to record zero pounds of tension while holding the hauler when not in use. See Figure 1 below to understand this hauling process and where the sensor was installed.

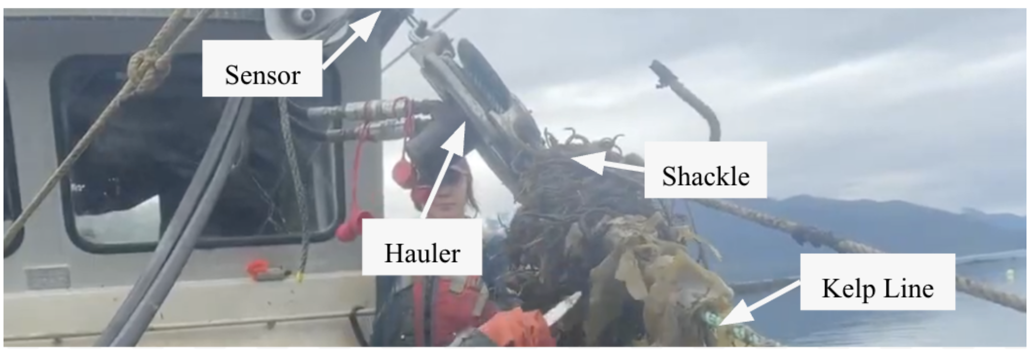

Figure 1. Photo of the kelp harvest during data collection. The SmartLink^2 Cyclops Nano sensor, which is positioned above the hauler, is not visible in the image. The shackle used to strip the kelp is hidden beneath the kelp wad. Photo courtesy of Jonny Antoni.

In the kelp hauling system pictured above, a shackle (out of sight behind the kelp wad in Figure 1) strips kelp from the line as a hydraulic hauler pulls the line out of the water. A worker assists by manually cutting kelp tangles off the line. The line is then manually managed/pulled as it exits the hauler. Figure 2 provides a simplified diagram of the system.

As seen in Figure 3, the force vector of the smartlink^2 Cyclops Nano sensor is not collinear with the tension vector of the hauling line. This results from the tension in the excess line that is being pulled manually out of the hauler. We estimate this tension, T_2 in Figure 3, to be less than 10% of T_1, so there is only a 10% error in the calculated tension values. This error is typically two pounds when the hauling system is at rest, and has a maximum error of 50 pounds. This uncertainty will be accounted for during motor selection.

3. DATA ANALYSIS

The sensor recorded hauler loads on June 4th, 2025, through two hauling sessions totaling 5 hours and 34 minutes. The first session was 4 hours and 9 minutes, and the second was 1 hour and 25 minutes. There was a brief (three minute) pause between sessions. The time resolution of the data is 1 second and the sensor is accurate to ±13 pounds.

Once the hauling process began, the sensor recorded approximately 20 pounds when the hauler was paused, presumably due to the weight of the kelp hanging on the line. Higher tension was recorded due to the dynamic loads

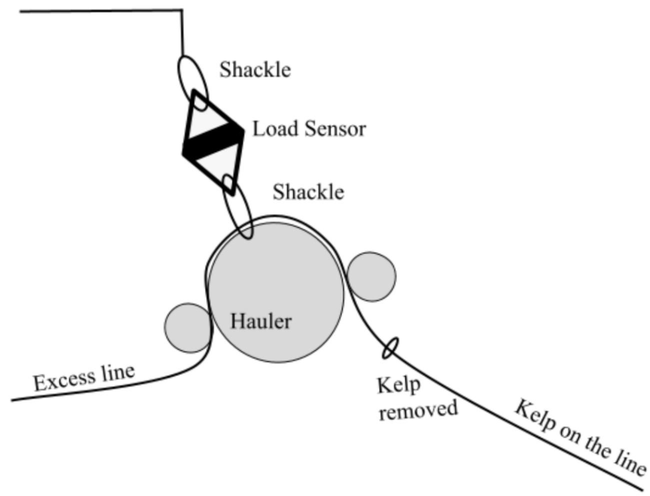

Figure 2. Diagram of the kelp harvest system, representing the setup shown in Figure 1.

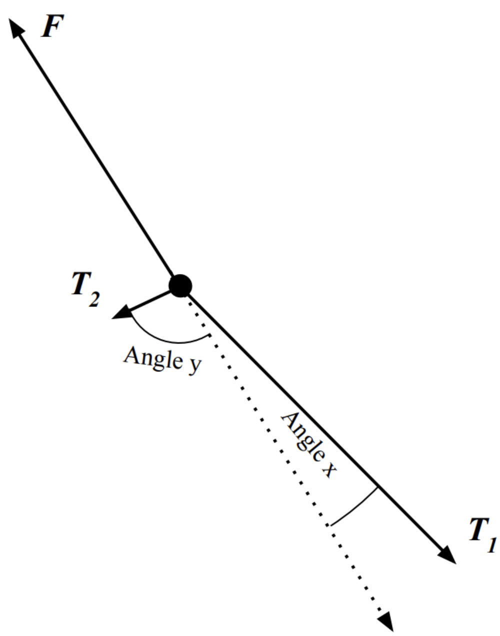

Figure 3. Free body diagram of the kelp harvest system. F is the force on the smartlink[2] Cyclops Nano sensor that is recorded. T_1 is the tension in the kelp line. T_2 is the tension in the excess line. Note angles x and y, the angles between the direction of the force on the sensor and T_1 and T_2, respectively.

of pulling the kelp line and stripping the kelp off as it passed through the kelp stripping shackle. Throughout the recording period, the average tension in the line was 40 pounds with a standard deviation of 60 pounds. The maximum tension in the line was 490 pounds. Table 1 summarizes key statistics of the two data sets separately and combined.

Throughout the duration of kelp hauling, there are many high tension periods that last approximately five minutes. During these periods, the tension often spikes above 300 pounds. Figure 5 shows an example of these large spikes by zooming in on a five minute time period. During this five minute period the tension in the line jumps between 150 pounds to 350 pounds. These spikes in the tension were caused by the process of removing the kelp from the line (cutting and tearing) and kelp blockages around the stripping shackle that build up as the kelp line enters the hauler.

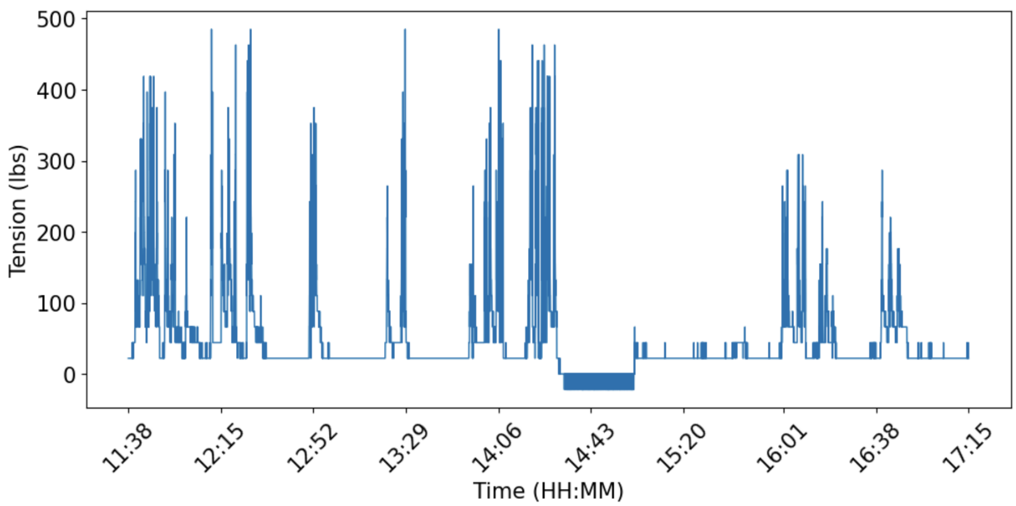

Figure 4. The tension in the line recorded over 5 hours 34 minutes.

Table 1. Statistics of the two separate .csv files and the combined data.

	Mean (lbs)	Standard Deviation (lbs)	Minimum (lbs)	Maximum (lbs)
Data Set 1	50	60	-20	490
Data Set 2	40	40	20	310
Combined Data	40	60	-20	490

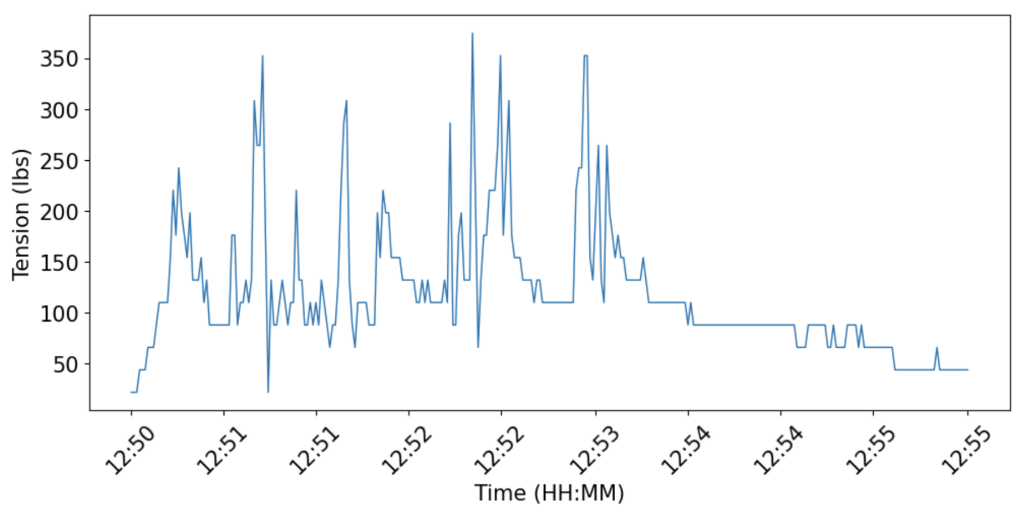

Figure 5. Tension mapped over five minutes, from 12:50:45 to 12:55:45.

An electric hauler system will need to meet the average load efficiently, while also having the necessary torque to satisfy the peak loads. Figure 6 illustrates the frequency at which different tensions occur. While the tension is under 100 pounds 80% of the time, the electric hauler will need the capacity to pull over 500 pounds of tension.

4. RESULTS

Sea Quester Farms requires hauling speeds up to one foot of line per second. While hauling, harvesters frequently stop the hauler to strip kelp, adjust lines, etc. Given these frequent stops, Sea Quester Farms' goal is to strip 100 feet of kelp line per hour. A maximum haul speed of 1 ft/sec ensures that the time required for hauling will not be limited by the haul motor. Multiplying the recorded tension by the desired hauling speed provides the electric motor power

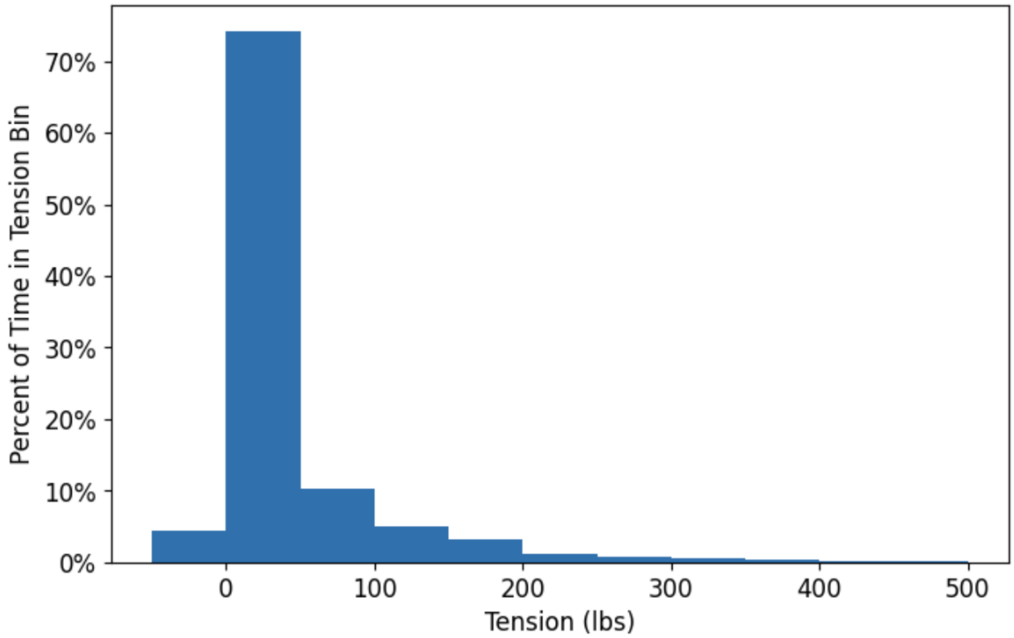

Figure 6. The percent of time in tension bins spanning between -50 and 500 pounds.

requirement. With tensions ranging from 40 pounds to 490 pounds and a peak hauling speed of 1 ft/s, the hauler must have the capacity to provide 50 to 700 Watts of pulling power.

While the tension and hauling speed are design criteria for Sea Quester Farms, the rotational speed of the sheave and the required torque will depend on the diameter of the sheave. Similarly, the rotational speed and torque of the motor will depend on the gear ratio of any gearing installed between the sheave and the electric motor, in addition to the diameter of the sheave. Minimizing cost and weight will likely require using a gear box that allows the electric motor to spin much more quickly than the hauling sheave.

Future work must determine the type of motor, gear ratio, and sheave that most cost effectively meet the aforementioned tension and power requirements. With the data collected from Sea Quester Farms, it has been possible to begin this work and calculate the typical tension in the line when harvesting kelp. Understanding these tension values provides further insight for the design of an electrical hauling system. Using electrical hauling systems in kelp farming would allow kelp farmers to turn off their diesel engines and use a battery to power the hauling process instead of hydraulics. To bring this carbon-emission conscious system into practice, specific motors, batteries, and electrical circuits must be designed to create the most efficient system. With the help of Sea Quester Farms, the implementation of this specific electric deck gear is one step closer for fishermen in Alaska, especially kelp farmers.

5. ACKNOWLEDGMENTS

Thank you to Sea Quester Farms, especially Jonny Antoni, for installing the smartlink^2 Cyclops Nano sensor into their hauling system and recording the data that made this analysis possible.