Experimental Verification of a Simple Model for Transverse Vibration in a Tensioned Rope

Dave Custer's write-up of SP255 experimental work
conducted by Dany, Rod, and Elizabeth

Summary To verify the model of rope oscillation developed in SP255 class on Feb 13, a rope was tensioned and plucked like a guitar string. The rope length and weight, the length of the tensioned rope segment, the tension, and the number of cycles were recorded. The measured frequency was then compared to the frequency predicted by the model. Even though these tests were conducted at tensions well below those expected during climber fall arrest, 60 % (1 σ) of the experimental results are were within 6% of the prediction and no results differed by more than 13%. The close match between the model and the experimental data suggests that the model provides an accurate enough prediction of the frequency of oscillation to make recommendations on fall geometries that might be prone to coupling energy from an oscillating rope into a carabiner gate.

Introduction

In order to determine whether oscillating ropes can couple energy into carabiner gates to precipitate open gate carabiner failure, it would be handy to be able to predict the oscillation frequency of a length of rope under the conditions expected during climber fall arrest. A simple model has been developed to predict rope oscillation frequency (http://web.mit.edu/sp255/www/produce/rope_oscillation_model.pdf); this research determines how close the model is to experimental results.

Methods

Basically, lengths of rope were tensioned with weights and plucked like a guitar strings. The rope length, tensioning weight, time, and number of oscillations were recorded. The rope's linear density was determined by measuring the rope's weight and length and then dividing. With only slight modifications, 4 different combinations of weight and length were tested: 25 lbs/284 in, 50 lbs/288 in, 25 lbs/448 in, and 25 lbs/446 in. (Would be nice to have a figure here.)

Results

The linear density, recorded lengths, tensions, times, & cycles are listed in Appendix 1 along with the resulting measured frequency of oscillation, which is compared with the model. In general the measured results are close to the predicted results. The standard deviation of the ratio of measured to predicted frequency is 6%; thus, one would expect 99% of measured frequencies to be within 18% of the predicted frequency.

Conclusion

The model for rope oscillation frequency is pretty good. We can use it to predict fall geometries that are prone to coupling rope oscillations into carabiner gate oscillation.

Appendix 1: spread sheet results

analysis of rope oscillation data taken on Monday, March 20, 2006 by Dany, Rod, & Elizabeth rope linear density = 0.07 kg/m (7.25 lbs/155.5 ft)					
Length (in)	Weight (lbs)	Time (s)	Cycles	Observed ω	Observed/ Model ω
284	25	37	100	16.98	0.978
284	25	30	90	18.85	1.085
284	25	30	87	18.22	1.049
284	25	30	84	17.59	1.013
284	25	30	85	17.80	1.025
288	25	30	79	16.55	0.966
288	25	30	82	17.17	1.003
288	25	30	78	16.34	0.954
287	50	30	109	22.83	0.939
287	50	30	105	21.99	0.905
287	50	30	110	23.04	0.948
287	50	30	101	21.15	0.870
287	50	30	110	23.04	0.948
287	50	30	103	21.57	0.887
287	50	30	105	21.99	0.905
448	25	30	53	11.10	1.008
448	25	30	49	10.26	0.932
448	25	30	55	11.52	1.046
448	25	30	56	11.73	1.065
448	25	30	57	11.94	1.084
448	25	30	55	11.52	1.046
448	25	30	55	11.52	1.046
448	25	30	55	11.52	1.046
446	50	30	73	15.29	0.977
446	50	30	72	15.08	0.964
446	50	30	71	14.87	0.951
446	50	30	70	14.66	0.937
446	50	30	77	16.13	1.031
446	50	30	72	15.08	0.964
446	50	30	72	15.08	0.964
446	50	30	73	15.29	0.977
446	50	30	70	14.66	0.937