

Ergonomics Evaluation of a Rail Car Riding Platform

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Abstract: Railroad maintenance regularly involves replacing sections of rail, replacing ties, or replenishing the stone that forms the roadbed (ballast). Oftentimes a work train is used to move large amounts of these materials from storage locations to the work site. Railroad maintenance-of-way employees can ride on the side of the work train freight cars while traveling to the work site, while traveling to sidings to accommodate other train traffic, or while serving as the engineer's lookout during train movements (protecting the point). While riding a freight car, the rider's hands and feet are usually placed the same distance anterior to the center of mass as they ride on a vertical ladder on the side of the freight car. This study aims to quantify the biomechanical advantage gained by using a temporary platform, which moves the feet to a location more directly below the center of mass, while riding on the side of freight cars. The 10" x 10" ruggedized riding platform also provides a more stable footing than standing on a 5/16" cylindrical ladder rung. An analysis of 27 shove movements over the same span of trackage was performed. The peak accelerations in all three planes, along with the corresponding grip force (lb.) was measured for each movement, as well as the grip force that was used to hold while under steady-state riding conditions. Trials were performed using two temporary riding platform prototypes as well as traditional riding techniques without the use of a temporary riding platform. The acceleration and grip data collected while using the temporary riding platform show improvements in the comfort, strength capability, and biomechanical factors while riding on railroad freight cars.

Keywords: *Railroad, Grip Strength, Riding Equipment, Human Acceleration/ Shock*

1. Introduction

The temporary riding platform serves as a place for employees to safely stand on the side of a rail car and ride for longer durations and distances when distributing track construction materials. The tie distribution gang unloads railroad ties using an OTM Tracker tie crane in combination with a Brandt high rail truck. The Brandt truck is a Freightliner rail car mover, capable of moving a consist of up to 10 loaded gondola cars at a time. The gang estimated that they typically use seven gondola cars, and on the day of testing, four loaded gondola cars were used. Approximately 2000 feet of siding was available for making repeated shove movements that ranged from 6 to 8 miles per hour.

The purpose of this study was to evaluate the removable riding platform for use on maintenance-of-way track construction material distribution trains.

2. Methods

A prototype temporary platform made of 3/16-inch steel and 13 pounds in weight was evaluated. The platform provided a 10-inch x 10-inch standing surface and accommodated freight car ladder widths of 13 inches to 20 inches. An adjustment wheel was used to operate a locking mechanism that interfaced with the side brace of the rail car ladder system, wedging it in place.

Tri-Axial Acceleration data was collected using a NEXGEN Ergonomics Biometrics Ltd DataLog Model MWX8 data acquisition device. The DataLog system uses a multimedia card to store data as it is collected in real-time. A DataLog indent cable was also used to keep track of relevant occurrences during data collection and to allow for synchronization with collected

video. Two Biometrics Series 2 tri-axial accelerometers, with a working range of ± 10 Gs, were used with the DataLog. The accelerometers were affixed to the gondola car near the location of the handhold using a magnetic mounting plate and oriented such that the X-axis was in the longitudinal direction, the Y-axis was in the vertical direction, and the Z-axis was in the lateral direction. The accelerometers were set to record acceleration data in the range of 0-100Hz. The sampling rates for the two accelerometers were set to 500 Hz and 50 Hz.

Using Tekscan™ hand force measurement equipment, real-time hand forces were measured while holding and riding the gondola car throughout the range of measured accelerations. Real-time grip force data was collected synchronously with acceleration data as well as all video camera views.

Figure 1 shows the Tekscan™ force sensors for the hand, glued to a thin cotton glove, which held the sensors in place relative to the digits of the hand. There are 69 sensors distributed over 18 circuits, as shown on the left side of Figure 1. The right side of Figure 1 shows the “circuit board” for the sensors. A protective thin cotton glove was placed over the force sensors to keep the sensors protected and from moving when inserted into the leather, and Ninja Ice™ gloves.

The gross grip force was measured by the Tekscan system for each hand. Grip force was calibrated using a grip dynamometer before and after each type of glove was used. The Tekscan system measured data at 50 HZ.

The peak grip force, which occurred at the peak perturbation during the shove movement was recorded. In addition the steady-state grip force was also recorded. One subject was used for the testing: a 57-year-old man weighing 225 pounds with a height of 74 inches. The study focused on the forces exerted by the leading hand, since the method of riding was fixed, whereby the subject used the trailing arm and hand in a “chicken wing” posture to wrap around the ladder—the preferred posture.



Figure 1: Tekscan force sensors worn under the work glove (left, center). Tekscan system in use (right).

Figure 2 shows the instrumentation arrangement on the rail car, complete with the temporary riding platform. A GlobalSat DG-100 data logger was used to collect GPS information throughout the duration of the data collection. Position, time, date, speed, and altitude information was stored to internal memory on one-second intervals. Three video cameras were used throughout the duration of the data collection: a Sony Handycam and two GoPros. The video clips were synchronized. One GoPro camera was focused on the overhead view of the rider and the other was focused on the coupler to show the start and stop of each movement. The Sony camera was used to show the broader context of the train movement.

Software developed by Biometrics Ltd. was used to export the relevant acceleration raw data. Acceleration data files were imported to the Biometrics software and exported as comma-separated .TXT files with the data shown in the engineering units of meters per second per second (m/sec^2). The files were then imported to Excel for smoothing. Excel was used to apply a simple moving average with a window size of 10 data points. The first smoothed data point is calculated by taking an average of the 1st through 10th data points, as described in Equation 1. The second smoothed data point is calculated by taking an average of the 2nd through 11th data points, and so on.

$$\text{Smoothed Data Point \#1} = (d1+d2+...+d10)/10 \quad (1)$$

A 10-sample window represents 1/50th of a second and best represents the net acceleration of the rapidly-occurring slack events. This window size was also effective at removing the high-frequency vibration “noise” that is not representative

of the translational movement felt during a slack event (in the case of the X axis) or other movement events (in some cases for the Y and Z axes).

Data smoothing was applied to the X-axis (longitudinal) and the peak was located for each movement. Since the peaks could be in either the positive or the negative direction, the peak was determined to be the largest absolute value acceleration. However, the polarity of the acceleration was maintained separately for analysis purposes. The smoothed accelerations in the remaining two directions were also recorded for the same moment in time.

The independent variables tested were glove type (Ninja Ice™ and Leather with a vented back), and step type (new version, old version, and none). The freight car type was fixed—what is called a gondola car. In all, 27 shove movements were made over the same 2000-ft siding, which was made up of jointed rail.

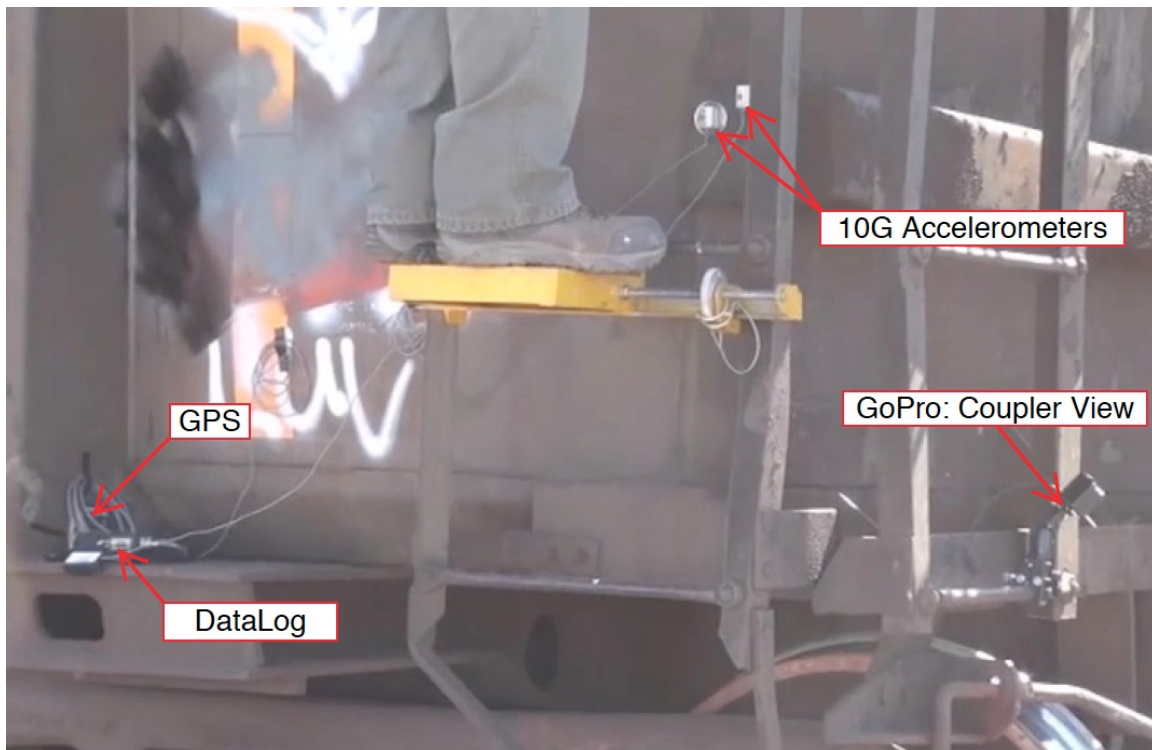


Figure 2: Temporary riding platform and freight car instrumentation.

3. Results

3.1 Acceleration Profiles of Riding Platform

Of the 27 shove movements, 14 were performed while wearing the Ninja Ice™ gloves and 13 were performed while wearing the leather gloves with vented back (See Table 1). The average peak accelerations were similar for both glove types: 1.06 m/s² and 0.99 m/s², respectively.

Table 1: Acceleration data by glove type.

Direction of Acceleration	# of Trials	Average Maximum Longitudinal Acceleration (m/s ²)
Ninja Ice	14	1.06
Vented Leather	13	0.99
Grand Total	27	1.03

Table 2: Acceleration data by step type.

Step Type	# of Trials	Average Maximum Longitudinal Acceleration (m/s ²)
Newer Step	19	1.08
NO Step Used	2	0.80
Older Step	6	0.95
Grand Total	27	1.03

The main difference between the older version of the step and the newer version is the roughness of the standing surface. The older version featured a more aggressive tread, where the newer version was smoother (See Attachment B). It was thought that both steps provided an equal amount of traction under the favorable weather conditions during testing, and therefore, the newer step was used for 19 trials, while the older version was used for 6 trials, and no step was used for 2 trials. (See Table 2). When no step was used, the average maximum longitudinal acceleration was 0.80 m/s² and the weighted average maximum longitudinal acceleration was 1.05 m/s² when a step was used.

Table 3 shows that for 14 of the trials, the maximum longitudinal acceleration occurred as a buff (bunching of freight car slack) at the moment the shove began. In 4 of the trials, the maximum longitudinal acceleration occurred as a draft (stretching of freight car slack) near the very end of the shove. For the other 9 trials, the maximum longitudinal acceleration occurred mid-way through the ride, as either a buff or a draft. The average peak accelerations were similar for buffs and drafts: 1.01 m/s² and 1.06 m/s², respectively.

Table 3: Acceleration data by direction of acceleration.

Direction of Acceleration	# of Trials	Average Maximum Longitudinal Acceleration (m/s ²)
Buff	20	1.01
initial start up	14	1.14
mid-ride	6	0.71
Draft	7	1.06
mid-ride	3	1.05
stopping	4	1.08
Grand Total	27	1.03

For the purposes of predicting the load limit for the step, the positive peak accelerations in the vertical direction were noted for each trial. The step was considered to be a component of a rigid system, and therefore, the instantaneous peak accelerations were observed. Of the 27 samples, the maximum vertical acceleration was found to be 6.4 m/s². The average was 5.3 m/s² with a standard deviation of 0.7 m/s².

3.2 Riding Platform Load Rating Analysis

Two factors come into play in determining the load rating for the riding platform: rider anthropometry, the additional loading acting upon the rider due to mechanical perturbations experienced while riding, and a safety factor. To ensure accommodation of a wide variety of body statures, the 95th percentile male body weight is used—275 pounds (University of Michigan 3DSSPP). The additional vertical loading (acceleration) acting upon the rider due to mechanical perturbations, from section 3.1 above, is a factor of 1.65 (acceleration in the vertical direction was 65% greater than the force of gravity). This was the maximum acceleration recorded across the 27 trials. Using a safety factor of 2, this equates to a load rating of 907 pounds.

3.3 Riding Duration and Recovery Time Analysis

Current methods of riding a shove (without the step) call for a 5-minute rest period for every half-mile traveled. Below are the results of the duration and recovery time analyses. Average grip force (across glove types) while riding on the ladder rung was 12.1 pounds. The average grip force while riding on the platform (across both designs) was 4.6 pounds—a 62% reduction in grip force. Table 4, below, shows the grip endurance time for each type of riding step for men (ACGIH, 2016). The average male grip strength for men between 50-59 years of age is 101.1 pounds (Mathiowetz, et al., 1985). The endurance time for the average man (in terms of grip strength) was 17 minutes when riding on a ladder rung and 81 minutes when riding on the platform—a 376% increase in riding time.

Table 4: Endurance analysis for men

Type of Step	Average Male Grip Strength (pounds)	Grip Force Required (pounds)	Endurance (minutes)
Ladder Rung	101.1	12.1	17
Riding Platform	101.1	4.6	81

Table 5: Endurance analysis for women

Type of Step	Average Female Grip Strength (pounds)	Grip Force Required (pounds)	Endurance (minutes)
Ladder Rung	57.3	12.1	7
Riding Platform	57.3	4.6	32

Table 6: Recovery time analysis for men

Type of Step	Task Duration (minutes)	Recovery Time (minutes)
Ladder Rung	30	13.8
Riding Platform	30	none

Table 7: Recovery time analysis for women

Type of Step	Task Duration (minutes)	Recovery Time (minutes)
Ladder Rung	30	52.7
Riding Platform	30	3.1

Table 5 shows the grip endurance time for each type of riding step for women (ACGIH, 2016). The average female grip strength for women between 50-59 years of age is 57.3 pounds (Mathiowetz, et al., 1985). The endurance time for the average woman (in terms of grip strength) was 7 minutes when riding on a ladder rung and 32 minutes when riding on the platform—a 357% increase in riding time. Table 6 shows the recovery time for men when the riding time is 30 minutes long. When riding on the ladder rung, the recovery time is 13.8 minutes. When riding on the platform, no recovery time is needed for a riding time of 30 minutes (ACGIH, 2016). Table 7 shows the recovery time for women when the riding time is 30 minutes long. When riding on the ladder rung, the recovery time is 52.7 minutes. When riding on the platform, the recovery time is 3.1 minutes (ACGIH, 2016).

A biomechanical analysis of each riding posture was performed. But the analysis was not sensitive to the subtle riding posture differences between riding on the ladder rung vs. riding on the Step. In particular, the biomechanical model does not account for arching of the spine, which is done to move the body's center-of-gravity closer to the step—reducing grip effort needed and upper body strength needs. Nevertheless, it was the authors' experience that the Step reduced upper body strength needs and reduced fatigue of the low back.

3.4 Riding Methods Analysis

The easiest riding method on the gondola car tested was the chicken wing method. This method was preferred by the author vs. the two-handed method. It allows for getting closer to the ladder and reduces the amount of grip force needed of the lead hand.

4. Discussion

The accelerometry data showed to be lower than the normative data collected across Houston and Roseville yard movements and controlled yard movements conducted in Searcy, AR. This is attributed to the difference between RCL operations and using a car mover to propel the cut of cars. In addition, the average speeds were slightly lower (6-8 MPH) than in the prior studies (10-12 MPH).

Based on the vertical acceleration data measured across 27 trials, the additional G forces to be accounted for due to riding perturbations equals 0.65 G. Thus, to account for a 95th percentile male, weighing, 275 pounds, the Step needs to withstand 454 pounds. Adding a safety factor of 2 equates to 907 pounds as a load rating for the step.

Potential design improvements include:

- Larger threaded adjustment rod with coarser threads.
- Lighter gauge steel or switch to aluminum in order to reduce weight.
- Round corners and edges.
- Revert to previous version's more "aggressive" tread.

- Wider adjustment wheel for ease of use.

The riding platform or Step significantly increased riding time before fatigue sets in for men and women. For the average man (in terms of grip strength), the riding time increased from 17 to 81 minutes—a 376% increase in riding time. For the average woman, the riding time increased from 7 to 32 minutes—a 357% increase in riding time. Recovery time needed for the maximum riding time of 30 minutes for men, using the Step, was 0 compared with 13.8 minutes when riding on the ladder rung. (If the riding time was the maximum riding time of 81 minutes without a break, the needed recovery time is 5 minutes). Recovery time needed for the maximum riding time of 30 minutes for women, using the Step, was 3.1 minutes compared with 52.7 minutes when riding on the ladder rung.

The optimum riding method for the gondola car observed and tested was the chicken wing method, which allows the user to get closer to the car ladder, reducing grip effort, upper body strength demands and low-back fatigue—relative to the two-handed riding method.

5. References

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