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Ergonomics Evaluation for a Proposed Lighter-Weight Brake Stick for Railroad Freight Car Hand Brake Operation

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Abstract: Railroad freight cars are equipped with a hand brake to prevent the unintended movement (or to control the movement) of the freight car and other connected freight cars. Hand brakes may be used to secure a single freight car or an entire freight train, which involves setting several hand brakes, the required number of which are determined through a combination of railroad policy, overall tonnage, and track grade. The most common hand brake design uses a wheel, which is rotated clockwise to set the brake and counterclockwise to release the brake. The hand brake wheel is typically mounted overhead for a person standing on the ground. Safety rules require Train, Engine & Yard Service (TE&Y) Employees to mount freight cars and to stand on the sill or platform when operating the hand brake by hand. Railroad employees can use brake sticks to operate freight car hand brakes from the ground, eliminating the need to climb onto the freight car or to foul the track. Depending on railroad policy, the use of a brake stick is sometimes required. In this study, a total of 13 railroad employees; 8 remote control locomotive (RCL) conductors, 2 local conductors, 1 through-freight conductor, and 2 members of the car department; were observed during their typical work shifts. Instead of using the 5–8-pound metal brake sticks that they were accustomed to, they were provided with a 2-3 pound carbon fiber/Kevlar brake stick. Throughout their work shifts, railroad employees were interviewed to document their interactions with, and observations regarding, the lighter-weight brake stick (LWBS). From an ergonomics, comfort, and ease of use perspective, the LWBS was generally preferred over the metal brake sticks. Metal brake sticks have some advantages, such as length adjustability and overall reach, but for most applications the LWBS is a suitable alternative to metal brake sticks.

Keywords: Railroad, Brake Stick, Freight Car Hand Brake

1. Introduction

Railroad employees use brake sticks to operate freight car hand brakes from the ground, eliminating the need to climb onto the freight car or to foul the track when setting the hand brake without a brake stick (see Figure 1).

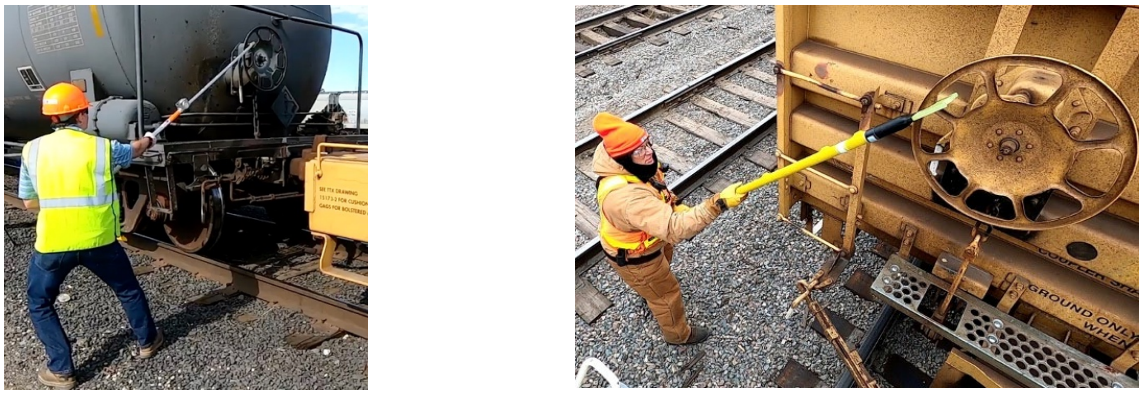

Figure 1. Metal brake stick (left) and Lighter-weight brake stick (right).

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In this study, a total of 13 railroad employees were observed during their typical work shifts. Instead of using metal brake sticks, they were offered the use of a lighter-weight brake stick (LWBS). Four fixed-length LWBSs were made available to each employee during the normal course of their duties. The railroad employees were also interviewed to document their interactions with, and observations regarding, the LWBS.

This research aims to answer the question: Should the LWBS should be approved for widespread railroad use from a human factors and ergonomics perspective? In Section 2, the ergonomics features of the LWBS are identified, and common user observations are presented. Section 3 examines how brake sticks are typically used in the field and the related ergonomics considerations. A summary of human factors and ergonomics observations and considerations for the LWBS are detailed in Section 4. Finally, the conclusions are given in Section 5.

2. Ergonomics Features of the LWBS

In recent years, railroad suppliers have developed a light-weight brake stick that uses carbon fiber structural tubing encased in a safety yellow Kevlar sleeve. The Kevlar sleeve provides visibility, a texturized gripping surface, and an encasement for the 3 magnets that are spaced out along the same side of the shaft. (The shortest brake stick only uses 2 magnets.) The head of the brake stick has been machined out of a variety of materials in the past, with the current version made from a ceramic-infused plastic. The ceramic-infused plastic is used due to its light weight and its ability to flex slightly under mechanical stress. A rubber end cap or boot is used to help keep the hands from slipping off the end of the brake stick.

2.1 Design Observations

In addition to the basic design elements listed above, the LWBS is offered in four fixed-length models. One manufacturer of metal brake sticks also offers four models of telescoping brake sticks, each one spanning a unique range of lengths (see Table 1).

Table 1. Brake stick specifications.

LWBS	Fixed Length (in.)		Weight (lb.)
Model A	37.0		2.0
Model B	48.0		2.2
Model C	67.0		2.6
Model D	75.0		2.8
Metal Brake Stick	**Length-fully retracted (in.)**	**Length-fully extended (in.)**	**Weight (lb.)**
Model A	27.0	42.0	5.0
Model B	39.0	62.5	6.0
Model C	49.0	81.0	7.0
Model D	67.0	104.0	8.0

2.2 Field Observations

Videos taken during field observations, coupled with employee interviews, provided “user-centered insights” (Wickens, C. et al., 1998) on the LWBS as well as ideas for design improvements. The employee interviews were not formalized, but rather a consistent line of questioning was worked into conversation while the employees were performing their duties.

Some conductors store their brake stick on the locomotive while others store them in the bed of their company pickup truck or even on the track switch masts located throughout the yard. It was reported that two of the most common

failure mechanisms for metal brake sticks are when the telescoping pole becomes bent or when the adjustment mechanism fails. Under either circumstance, the telescoping pole can get stuck in either the retracted or extended position. Roughly half of the observed metal brake sticks were equipped with a magnet. It is not clear if these brake sticks ever had the magnet since this is an optional feature.

Most employees cited the weight of the current brake stick offerings as the main factor for avoiding brake stick use when not required. The second reason they chose to avoid brake stick use is the lack of availability. Some train yards have brake stick holsters installed on the lighting poles, which were tested and were shown to work with the LWBS. The magnets on the LWBS also provide opportunities for the brake sticks to be stored strategically on metal surfaces throughout the yard.

2.2.1 LWBS User Feedback – Beneficial Features

None of the 13 railroad employees have ever used a LWBS in the past and all were surprised by the weight of the brake stick when they picked it up. They unanimously cited the lighter weight as the single most important benefit of the LWBS. A hand brake can be operated in less than 15 seconds on average. Consequently, the cumulative amount of time spent carrying the LWBS during the work shift is usually greater than the amount of time they are used for hand brake operation. Conductors cited the handling of the brake stick as the task that is most benefitted by the LWBS, but also noted that positioning the head of the brake stick on the brake wheel requires less effort when using the LWBS.

It was noted that the LWBS is completely non-conductive. This could be an important feature if there were ever a circumstance where the brake stick could contact an electrical source or where sparks from a glancing blow to a metal surface could lead to an explosion or fire.

Throughout the blizzard conditions that occurred during train yard observations, it was noted that the LWBS handle does not get as cold as the handles of the metal brake sticks. The textured Kevlar jacket also provided a better grip, especially in wet conditions, than the etched metal handle of the metal brake sticks. (The observed metal brake sticks were worn; the effects of wear on the ability to grip the LWBS handle are unknown.) The magnets, which protrude about ½ inch, served as stops to help keep the hands from sliding along the LWBS shaft as well.

Multiple magnets in each brake stick handle allow for the ability to hang the LWBS horizontally, in contrast to the single-magnet metal brake sticks which must hang vertically. As a result, there are more possible storage locations for the LWBS. All magnets must be in contact with a metal surface for them to hold the weight of the brake stick, therefore care must be taken to ensure that the intended hanging location is free of impediments.

2.2.2 LWBS User Feedback – Suggestions

If the LWBS could be collapsed, or otherwise folded, the options for stowing and carrying it would increase. Even so, every study participant stated that they would prioritize the lighter weight of the LWBS over the ability to collapse/shorten the brake stick when not in use.

Some users noted that a smooth protective plastic band, used in three locations along the handle, created a potential slip point for their hands. This was especially evident when wet. The top two plastic bands cover the warning label and the glow-in-the-dark band near the head of the brake stick and are not located in areas likely to be gripped. However, the plastic band nearest the end cap is in the zone where the user would exert a power grip.

The rubber end cap is useful for cushioning when accidental contact occurs with other surfaces. It also provides a stop for the brake stick user's hand. It was suggested that a wider end cap could help prevent the user's hand from slipping off the end of the brake stick during use.

Some brake stick users noticed that the LWBS was more likely to slip off the hand brake wheel than the metal brake sticks. One possible explanation for this is the shape of the hooked portion of the brake stick head. The LWBS hook is more rounded, causing the brake wheel to settle more toward the outside portion of the hook (away from the brake stick shaft). The metal brake stick hook is angled such that the brake wheel settles more toward the inside portion of the hook (toward the brake stick shaft) thus reducing the likelihood of the hook slipping off unexpectedly during hand brake operation.

2.3 Accessories

Several study participants stated that brake stick users will often create their own sling or carrying strap for the brake stick. It was thought that a similar sling could also be useful for carrying the LWBS. This could work for the shorter two brake sticks and possibly longer ones as well, however, it was noted that it would be difficult for the sling to hold the longer brake sticks in a vertical position to avoid making accidental contact with someone or something, such as equipment on adjacent tracks.

In a 2006 focus group study, the Federal Railroad Administration (FRA) found that Remote Control Locomotive (RCL) conductors desire a vest that will make wearing and holding the necessary equipment and tools less cumbersome and

more comfortable (Reinach and Acton, 2006). In this regard, several RCL conductors wondered if it would be possible to build a method of carrying the brake stick directly into the RCL vest. They stated that they would not have considered adding additional weight to the vest in the past but the advent of the LWBS makes this a possibility now. However, unless the holster kept the brake stick in the vertical position, the same concerns regarding making accidental contact with someone or something would still apply.

3. Using Brake Sticks

With fixed-length brake sticks, one of the greatest challenges is to select the length that will be most appropriate for each application. In general, longer brake sticks provide more versatility while shorter brake sticks are easier to carry and stow. All brake stick users must recognize when their brake stick is too long or too short for the task at hand and refrain from using it in these instances.

3.1 Approved Technique

Railroad rules warn brake stick users against exerting unnecessary force. Instead, brake stick users are instructed to "use a whole-body movement when applying effort." When this technique is used, the user does not rely on the momentum of the heavier metal brake sticks to provide additional torque on the brake wheel. Rather, from a physics perspective, the brake stick is merely a rigid component of the system, with the input force exerted solely by the user and under the control of the user.

The brake stick should be long enough to accommodate good biomechanics during hand brake operation: standing with feet shoulder-width apart, and a two-handed grip on the brake stick, without reaching overhead. When required, the brake stick should also be long enough to avoid fouling the red zone (See Figure 2).

Figure 2. A short brake stick results in poor biomechanics and fouling the red zone (left). A long brake stick nurtures proper biomechanics and staying clear of the red zone (right).

Brake sticks may be used to operate hand brake wheels, knuckles, and angle cocks located on the side nearest where the brake stick user is standing. The LWBS is also designed to push brake release levers, to adjust draw bars, and to arm end-of-train devices (EOT)s. Brake stick users should be aware of all railroad rules regarding the use of brake sticks and should understand which circumstances allow for the use of brake sticks.

4. Human Factors & Ergonomics

4.1 General Considerations

The mounting bolt of some hand brake wheels protrudes beyond the face of the brake wheel, which can contact the brake stick during use and cause it to slip off the brake wheel. The best way to avoid contacting the mounting bolt is to operate the hand brake from further behind the freight car, in the longitudinal direction. If the user stands too far back,

however, the effectiveness of the hook can be diminished, causing it to slip off the brake wheel. The most effective position was found to be one or two steps behind the brake wheel plane.

A longer metal brake stick may be needed to operate a hand brake while using good biomechanics and staying clear of the red zone. This is particularly true when operating high-mounted hand brakes or for shorter-statured individuals. High-mounted hand brakes were not observed during the field study, however, if a 75–104-inch reach is routinely required, then a metal brake stick would be recommended. In practice, yard conductors avoid setting high-mounted hand brakes when possible. For instance, they might opt instead to set the brake on a connected car with a more accessible hand brake wheel.

The powerful magnets in the LWBS handle can cause the brake stick to "snap" toward the surface it is being mounted to. If the brake stick user is not careful, the low-profile of the magnets can cause the fingers to be pinched in the ½ inch space between the mounting surface and the brake stick as the magnets draw the brake stick toward the mounting surface.

4.2 Length of Brake Stick

The two longest LWBSs permit the greatest range of utility in circumstances where a longer brake stick will not lead to issues with clearance on adjacent tracks or with stowage in the locomotive cab or crew transport vehicles. For instance, some railroads do not allow for the use of brake sticks less than 5 feet in length to reach across the drawbar to operate the brake wheel. In this scenario, only the two longest LWBSs would be allowed to be used.

4.3 LWBS Considerations for Yard Conductors

Yard conductors who stated that they generally opt out of using brake sticks indicated that they would consider using the LWBS if it was approved for use. The features that would most encourage LWBS use include: the ease with which they can be carried and having greater access/stowage possibilities while working in the yard.

4.4 LWBS Considerations for Local Conductors

The observed local conductor crew uses a pick-up truck while performing switching operations. Therefore, they indicated that they would prefer the longest available LWBS since they can easily stow it in the bed of the truck.

Other local jobs, however, may need to consider the length of their brake stick if they use a crew van during switching operations, or if they need to bring the brake stick into the locomotive cab while the train is underway. This shouldn't be necessary since there is usually room behind the grab irons on the exterior of the locomotive where the brake stick could be stowed.

4.5 LWBS Considerations for Through-Freight Conductors

Since through-freight conductors keep a brake stick in their possession, the shorter two LWBS options would be more convenient to carry with their grip (equipment). If it were possible to equip every locomotive with a LWBS, sizes up to the 67" version could be stored in the nose of the locomotive, eliminating the need for through-freight conductors to carry brake sticks with them.

4.6 LWBS Considerations for Mechanical Department Employees

The manager of mechanical maintenance and a RIP carman demonstrated the use of the LWBS at the RIP track. Carmen at the RIP track routinely set the hand brake on a newly repaired freight car before they move it out of the shop. They have been using the LWBS on a trial basis for about a month. At least five of the RIP carmen have tried the LWBS and are happy with its performance; there have been no complaints.

5. Conclusions

From an ergonomics, comfort, and ease of use perspective, the LWBS has several advantages over metal brake sticks in most circumstances. Every participant in the usability testing preferred the LWBS over the current metal brake sticks. Since the LWBS is not adjustable in length, brake stick users will need to ensure that the brake stick they select is long

enough to enable proper biomechanics during use. If a 75–104-inch reach is routinely required, a longer metal brake stick would best accommodate this need. Users should avoid reaching overhead and should be able to maintain control of the brake stick near their center of mass so that whole-body movements can be used to apply force. In general, longer brake sticks are preferred, however users should avoid selecting a brake stick that is too long, which could risk fouling adjacent tracks or could cause issues with stowing the brake stick.

Railroads could consider including additional tasks, such as "adjusting draw bars" and "arming EOTs" on the list of approved uses for the LWBS. However, it is important to note that the other approved brake stick models may not have been designed for these purposes, which could lead to confusion over which brake sticks are approved for these additional tasks.

Lab testing data, including pull testing for the head and for the end cap, crush testing, and 3-point testing on the Kevlar-wrapped carbon fiber shaft were provided to the railroad by the manufacturer prior to field testing. These tests provided a reasonable degree of confidence in the safety of performing this field testing. Accelerated life-cycle testing was also performed to address concerns about cumulative UV exposure to the Kevlar-wrapped carbon fiber shaft. This research focuses on the human factors and ergonomics features of the brake stick and offers no opinion on the failure testing or life cycle testing results.

6. References

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