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Concrete Buggy Operator Presence Control 3-Dimensional Convergence of Accident Reconstruction Technology

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Abstract: A biomechanical and human factors accident reconstruction was conducted to analyze the circumstances surrounding a construction workplace incident associated with a rubber tracked powered concrete buggy. The accident reconstruction consisted of machine testing, human surrogate biomechanical studies, and geometry analysis of a 3-dimensional computer model created from multiple laser scan data sources. Results of this study illustrate that the body position of the concrete buggy operator allowed the operator's abdominal mid-section to maintain activation of the drive clutch lever operator presence control (OPC) after his hands were released from the control. Alternative safe work procedures, ergonomic machine controls analysis, and product warnings and instructions are explored. This paper demonstrates the convergence of five independent 3-dimensional digital data sources representing separate aspects of the actual accident and allows novel accident reconstruction analyses that are geometrically accurate and reliable.

Keywords: Concrete Buggy OPC, 3-D Convergence, Accident Reconstruction

1. Literature Review

Powered concrete buggies with rubber tracks provide efficiency and maneuverability advantages compared to manual wheelbarrows. Rubber tracked powered concrete buggies are often used in the construction industry by offering balanced weight distribution to travel over wet and muddy ground, rough and uneven terrain, and loose sand and gravel. Powered concrete buggies also provide a significant reduction in the physical effort needed to transport heavy materials over long distances, allowing operators to set the speed and direction through controls at the operator's position. The following safe operating practices are contained in the power buggy industry safety literature (Chikusui Canycom, 2016; OSHA, 2021; Safety Provisions, 2020):

1. Be constantly vigilant in your work area and make sure you always know what is going on around you.
2. Conduct inspections of your worksite and your travel route for potential hazards before operating your machine.
3. Assess the physical conditions of the controls before using your machine.
4. Before operating your power buggy, read the operator's manual and familiarize yourself with its contents.
5. Take extra precautions to stay safe, such as mapping your route from load pick up location to your dump location.
6. Never put yourself between moving or fixed objects.
7. Use signal persons or spotters to protect employees on foot behind heavy equipment with an obstructed view.
8. Beware of obstacles when reversing or turning. Always operate slowly and keep two meters or more clearance.

2. Accident Description

An OSHA investigation of the workplace accident indicated that the concrete buggy operator was reversing the machine in a tight space (approximately 1-meter rearward clearance) between a skid-steer loader and a dump truck on a roadway shoulder, and he became caught between the machine control panel and the dump truck behind him. The machine OPC drive

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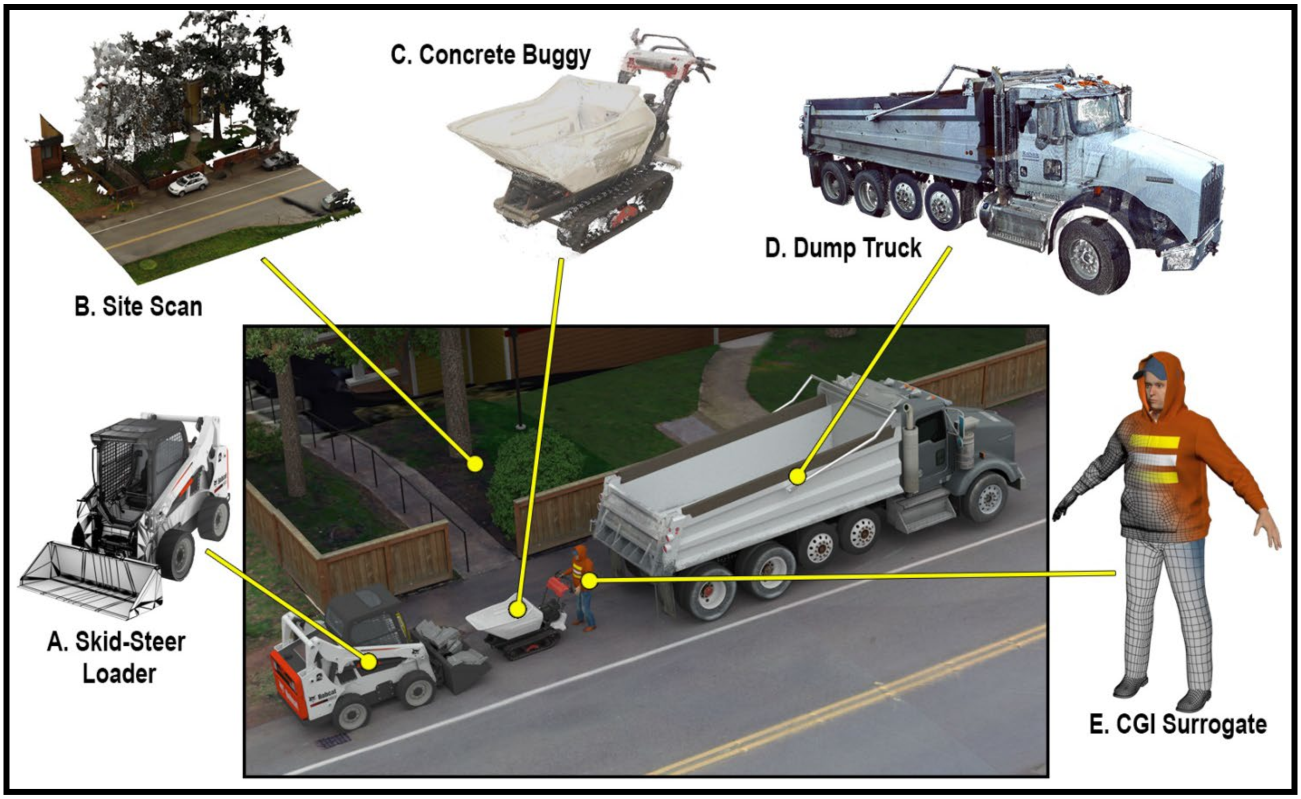

Figure 1. Data Sources Used for 3-Dimensional Accident Reconstruction Analysis

clutch lever remained engaged during the event after body contact with the machine operator. First responders moved the concrete buggy away from the rear of the dump truck, which released the operator who fell to rest on the pavement. Photographs of the skid-steer loader, dump truck, and concrete buggy operator on the roadway were taken immediately following the incident.

3. Accident Reconstruction Analysis

3.1 Data Capture

Analysis followed published methods that utilize the scientific method as a framework for accident reconstruction analysis (Knox, 2015). Preliminary investigation findings indicated that insufficient detail was recorded about the position of various components involved in the accident. This guided the novel convergence of digital data representing various physical components involved in the accident for the purpose of accident analysis within a 3-dimensional (3D) computer model. The reconstruction of this workplace incident involved analyzing the interaction between a skid-steer loader, the worksite location, a powered concrete buggy, a dump truck, and the concrete buggy operator, labeled A-E in Figure 1, respectively. To create 3D computer analysis for this reconstruction, 3D CAD models for each of the five data sources listed above were generated. Data was gathered for the incident site (B), the concrete buggy (C) and the dump truck (D) using a FARO Focus laser scanner. These scans were then used as templates to create the 3D CAD models using SolidWorks and 3D Studio Max (3DS).

The 3D CAD models for items B, C and D were then loaded together into 3DS. 3D CAD models for the skid-steer loader and concrete buggy operator from the ESi model archive were also loaded into 3DS, as well as two police photographs. Objects visible in the photos and measured by the laser scanner at the incident site were then used to adjust the skid-steer loader to the correct size. Photographs and anthropomorphic data of the operator were used to scale the operator to the proper size.

Figure 2. Camera Match Points for Convergence of Accident Site Geometry

Figure 3. Camera Match of Skid-Steer Loader, Dump Truck, and Operator with Accident Site (Accident Photo on Left)

3.2 3-Dimensional Convergence Computer Model Geometry Analysis

Figure 2 shows a side-by-side comparison of a photograph of the skid-steer loader at the site as it was positioned at the time of the incident (Figure 2A) and the 3D CAD model of the skid-steer loader placed in the 3D CAD model of the site created from the laser scan data (Figure 2B). Points one through six labeled in both images mark locations in the photograph and their corresponding location in or on the 3D CAD models. Points 3, 4 and 5 were utilized by 3DS to calculate a camera lens matching the one that was used to capture the photograph. Points 1, 2 and 6 were then utilized to position the skid-steer loader at the exact location it is shown in the photograph.

This process was then repeated for a second photograph taken on the day of the incident showing the back of the dump truck and the concrete buggy operator lying on the ground after being injured. Figure 3 shows a side-by-side comparison of both photographs used with each photograph being compared, in turn, to the computer-generated 3D CAD model for the site. The result is that both the dump truck and skid-steer loader are accurately located within the 3D CAD model of the site as they were on the day of the accident. It is now possible to move throughout the 3D CAD model of the site at will to analyze the actions of the concrete buggy operator and motorized concrete buggy with respect to the skid-steer loader, dump truck, and the rest of the site in the vicinity of the incident.

Figure 4. 3D Computer Model Analysis (Left) and Human Surrogate Studies (Right) of Accident

3.3 Human Surrogate Biomechanical Studies

Utilizing the classic systems approach that recognizes the interaction between the human user, the equipment, and the environment (National Safety Council, 1992), human factors testing was conducted with an exemplar concrete buggy and a dimensionally accurate mock-up of the back of the dump truck. The concrete buggy is placed in forward or reverse by a gear lever below the handlebars (see Figures 4A and 4B).

The operator presence drive clutch lever engages the transmission and moves the concrete buggy in the selected gear. The operator must maintain the OPC lever in the engaged position to continue moving the concrete buggy, and this is primarily maintained through holding the lever within the right-hand grip on the handle. A human surrogate operator displayed that the

Figure 5. Alternate Safe Work Procedure Using Two-Point Turn to Prevent Rear Contact with Dump Truck

horizontal portion of the drive clutch lever is at the height of the upper abdomen of the operator (Figure 4B). Rearward movement of the concrete buggy and surrogate into contact with the dump truck (mock-up) showed that the operator's torso is tilted forward (Figure 4D) as the concrete buggy continued to drive rearward. Continued movement of the concrete buggy to the rear depresses the surrogate operator's abdomen with the horizontal portion of the drive clutch lever, which holds the drive clutch lever in the activated position even without hands on the handlebars (Figure 4F).

3.4 Machine Drive Clutch Lever Cycle Testing

Cycle testing was performed on an exemplar concrete buggy to determine whether the drive clutch lever operator presence control (OPC) would stick to the handle or bind during normal use. Over 11,000 cycles were performed manually on the machine drive clutch lever OPC. Results of the machine cycle testing indicated that the drive clutch lever OPC did not stick or bind in the engaged position.

3.5 Accident Reconstruction

Analysis of the accident in the 3D computer model showed that the skid-steer loader bucket and the rear of the dump truck were located approximately 10 feet from each other when the operator positioned the front of the concrete buggy hopper adjacent to the skid-steer loader bucket to unload the concrete buggy hopper (Figures 4A and 5A). The available clearance for the operator between the concrete buggy rear handles and the rear of the dump truck was approximately 40 inches (1 meter). The operator proceeded to move the concrete buggy rearward and contacted the dump truck, forcing the horizontal portion of the drive clutch lever OPC into his abdomen, which prevented the drive clutch from disengaging (Figures 4C and 4D). After the operator released his hands from the machine controls, the drive clutch lever OPC remained engaged (Figures 4E and 4F). The operator's injuries from this accident were consistent with the concrete buggy crushing the operator against the dump truck in an essentially perpendicular orientation (Figures 4E and 4F).

Figure 6. Concrete Buggy On-Product Warning Label

4. Alternative Safe Work Procedures

Investigation of the accident revealed several safe work procedures that the concrete buggy operator could have employed to prevent his accident. These alternative safe work methods include: the operator maintaining a safe distance from obstacles, backing up and moving slowly, activating the controls to turn before moving the machine backwards, squeezing both handle brakes to stop the machine drive, and positioning his body to the left corner of the machine. Figure 5 demonstrates a safe work method with the concrete buggy making a two-point turn to avoid the struck-by hazard. An on-product warning label, as displayed in Figure 6, reminds operators to maintain a safe distance of two meters away from surrounding objects.

5. Conclusions

The application of 3-dimensional computer modeling and laser scanning technologies shows how innovative scientific approaches can help technical investigators understand and reconstruct this construction worksite accident. The practical use of these methodologies illustrates how science and technology can come together to efficiently converge on an accurate reconstruction of the accident and to safely analyze alternative safe work methods to prevent future similar powered concrete buggy incidents. The power of the 3-dimensional computer modeling and laser scanning technologies is that it transports investigators into the environment to see for themselves how and why the accident happened.

6. References

Chikusui Canycom (2016). *Off-Road Rubber Track Carrier SC45 Operator's Manual*. Fukuoka, Japan.

Knox, E.H. et al. (2015). Methods of Accident Reconstruction: Biomechanical and Human Factors Considerations. *Proceedings of the ASME 2015 International Mechanical Engineering Conference and Exposition, IMECE2015-53666,* 1-11.

National Safety Council (1992). Accident Prevention Manual for Business & Industry: Administration & Programs, 10th Edition, p. 65.

OSHA (2021). Requirements for Equipment and Tools. *29 CFR 1926.702(d)*.

Safety Provisions (2020). *Power Buggy Online Training Course*.