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Forensic Engineering Investigation of Personal Safety Equipment Failures

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Abstract

Fall accident prevention has always been critical for worker safety. This presentation will focus on two particular cases where hook attachments, commonly known as "pelican positioning hooks", failed. No one witnessed either fall or the conditions immediately before the fall. In August 2008 a worker fell from concrete formwork during construction of a Nuclear Power Plant in California. As the first workers arrived to assist the fallen worker they noted one leg of his safety harness had a pelican type positioning hook with the gate outside the main hook frame, while the hook on the other leg of his safety harness was still within the pelican hook mainframe. Later in March 2010 a maintenance worker on a 175 foot smoke stack in Pennsylvania fell while climbing the stack to start repair work. The first workers that arrived at his side, on the asphalt paved area, noted one leg of his safety harness had a pelican type positioning hook with the gate in a failed position outside the frame of the hook, the other leg of his safety harness the gate was within the hook frame and not in a failed position.

Keywords

Forensic Engineering, Positioning, Pelican Hook, Roll-out, Anchorage, Gate, Lateral Gate Load, Snaphook, Fall Protection, User.

History

These cases were falls from concrete formwork at a Nuclear Power Plant in California, and from a 175 foot high smoke stack in Pennsylvania. In each case the pelican type positioning hook gate was observed in the failed OPEN position (Figure 1) when the first co-workers arrived to assist their fellow worker. The daily procedure for the worker was to inspect the heavy duty pelican attachment hook and safety equipment. They most likely felt confident when connected to a solid anchorage, likely assuming the safety pelican hooks would prevent them from falling in case of an accidental slip. Confidence in the safety equipment would

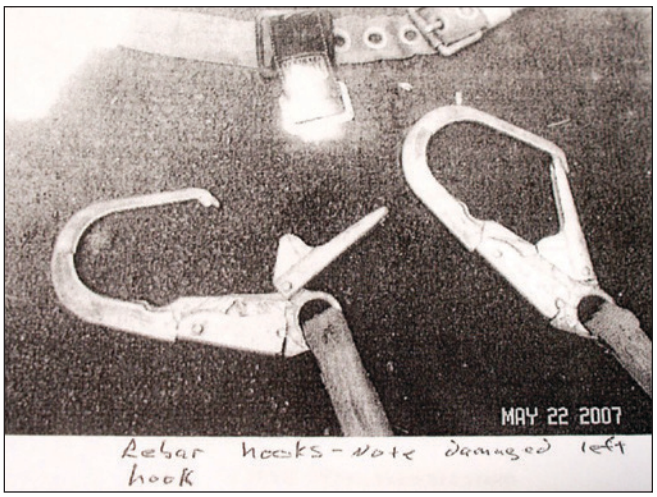

Figure 1
Left Hook gate Failed, Right Hook Not Failed.

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likely lead the workers to feel safe as each was getting into position to perform their assigned tasks. In the author's experience as a Certified Safety Professional, workers often fail to understand how easily these hooks can disengage from the anchorage in common work situations while performing tasks assigned. The weaker side load capacity of the safety gate, in accordance with the older version of the ANSI Z359.1 – 1992 standard, contributed significantly to this accident and the injuries incurred. The latest ANSI Z359.1[1], June 30, 2007 standards, Requirements for Personal Fall Arrest Systems, Subsystems and Components, increased the side loading requirements from 350 pounds to 3600 pounds on the safety gate thereby substantially increasing the safety of the worker. The weaker side loading capacity (of the safety gate) allowed by the older 1992 version of the ANSI Z359.1 standard contributed significantly to these incidents and the injuries incurred. Had the workers been using pelican hooks that met the latest standard, most likely neither accident would have occurred.

Terminology

Pelican Hook:

This safety hook gets its name from the profile that is similar to a pelican bird, having a large throat and small neck. This hook appears to be very substantial and well built, but can be dangerous because of the possibility of an unexpected roll-out failure.

Competent Person:

One who is capable of identifying existing and predictable hazards in the surroundings or working condition which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Anchorage:

A secure connecting point or a terminating component of a fall protection system to be used by a falling worker or rescuer that requires the use of a fall protection system.

Positioning Hook:

This safety hook is only to be used for a positioning hook and not to be used as a component of a fall arrest system. This hook is designed to allow the worker to be attached to and work hands free while still being properly attached to a solid anchorage

Positioning:

The act of supporting the body with a positioning system for the purposes of working hands free. However, if the worker slips and loses his balance, positioning hooks cannot be relied upon to stop a potential fall.

Gate:

The element of a connector that opens to receive an object and closes to retain that object.

Hook Gate:

A spring loaded secondary safety latch to prevent gate from disengaging from the anchorage. The gate must remain inside the main hook frame and not allow a roll-out unlatching it from the anchorage.

Fall Protection:

Any equipment, system or device that prevents an accidental fall from elevation or that mitigates the effect of such a fall.

User:

A person who performs activities at heights.

Warning:

From the Instruction Booklet[2], *"All persons using this equipment must read and understand all instructions. Failure to do so may result in serious injury or death."* This is from the manual for a specific safety positioning hook.

Roll-out:

A lateral movement of a Snaphook or carabineer resulting in unintentional disengagement from an anchor, connector or object to which it was coupled. The safety hook gets into a position that overloads the gate side load and unlatches it from the anchorage point attached.

Carabineer:

A metal loop with a spring-loaded gate used to quickly and reversibly connect to an anchorage, most notably in safety-critical systems. If the carabineer gets into a position that places a side load on the latch it can fail and unlatch from the anchorage.

Snaphook:

A connector comprised of a hook-shaped body with a normally closed gate or similar arrangement that may be opened to permit the hook to receive an object and, when released, automatically closes to retain the object.

Free Climbing:

Climbing a tower or other structure without attaching the personal safety equipment. This may save time but the worker must hang on to provide his protection and prevent a fall.

Grab Hook Fall Arrest:

A single line parallel to the ascent of the worker that has a safety line grab device to prevent a fall. Some worker must climb to the top to install the safety line to be used as fall protection. The safety line may be considered by a worker to be in conflict with task to be performed.

Investigation

The author's experience as a Certified Safety Professional, is that the worker usually realizes that they should inspect the equipment each day before using. Therefore the worker typically confirms the equipment is undamaged and still performing as usual. They typically look for cuts, wear in the strap portion, and verify that the hook and gate work with the gate locking within the main body of the hook's main frame. However, often workers do not understand that they are required to read or understand the manual and they may disregard the manual or disregard it's mandates. The worker may assume, when furnished with a properly fitted safety harness and two strap attachments with very solid heavy duty hooks, that he

will be safe if connected to a solid anchorage with the safety gate in place. They understand that the safety gate is to keep the hook from disengaging from the anchorage. Actually however, the pelican hook CAN-NOT be relied upon to prevent a fall while the worker is in position to perform the tasks assigned. The distinction between "holding in position" and "preventing a fall" is often misunderstood by the common worker. If the worker has access to the manual he will encounter requirements such as:

WARNINGS!

1) Inspect before each use.
2) Make sure all hardware connections are compatible.
3) Assure that snap hooks gates and safety gates are closed and locked.
4) Assure that safety gates are not load bearing.
5) Do not disable safety gates or locking keepers.

Unfortunately, designated "competent" trainers, as defined by OSHA, do not always understand how easily a gated safety hook can and sometimes does get into a position to allow roll-out, This can have life threatening consequences.

During site inspections of the most likely anchorage used in these two cases, it was demonstrated the pelican hook could move into a position where it would suddenly fail by rolling out. Once the hook had been secured to the anchorage it MUST NOT be able to disengage and allow the worker to slip and begin a fall. Although the equipment most likely appeared to the workers as heavy duty and foolproof and appeared to require thousands of pounds of force to break or fail, a safety gate on a heavy-duty-appearing pelican hook was actually required (under ANSI Z359.1-1992) to be tested for a static lateral load of only 350 pounds for 1 minute. It is not uncommon for the worker to maneuver the hook into a position that applies a lateral load far in excess of that required criterion that would stop a slip. If the workers read the warning statement to never apply side loads to the safety gate and obeyed that requirement the events would not have occurred.

In each of these cases analyses demonstrated how the hook could be placed into a position on the anchor that would roll-out and let the worker fall to a lower level. Attaching the positioning pelican hook onto a solid anchorage does not assure it would provide support to the worker by preventing a slip that could lead to a fall.

Two following examples illustrate two pelican hooks in the process of "rolling out" thereby leading the worker to start his fall. A slip is often the triggering sequence leading to a fall, once the fall starts the worker must have a separate "Fall Arrest System" to prevent an accident.

(Figure 2) This pelican hook was attached to a heavy steel 'X' brace to keep the worker in position. During routine movements the hook slid down and "rolled out" thereby allowing the worker to fall to the

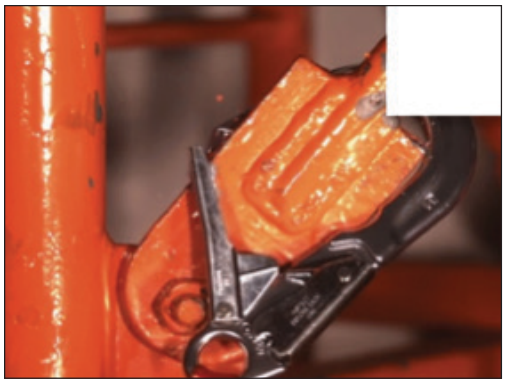

Figure 2
Gate of Hook being loaded laterally and gate is failing, allowing hook to roll out and disconnect.

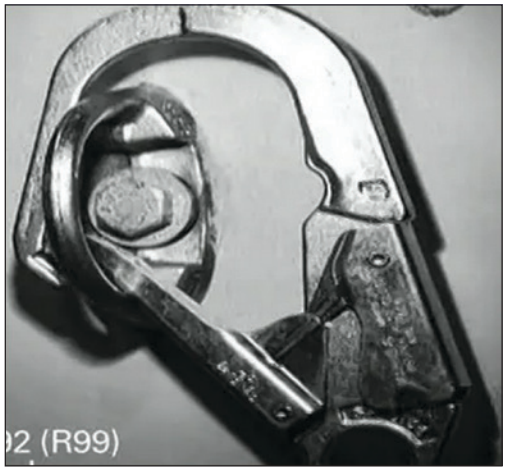

Figure 3
Gate is failing due to light gage metal bending and disengaging the gate. Hook will rotate and fail in roll out.

Figure 4
Left hook represents the latest Standard with the stronger design. While the Right hook represents the weaker earlier design.

deck below. As the hook slid down the diagonal, the gate was forced away from the main frame of the hook, the gate was laterally overloaded and disengaged the hook from the anchorage that was selected by the worker. This action forced the gate out of the main frame of the hook thereby destroying the hook's capacity to hold the worker in a safe position, and leading to a serious fall accident.

One well used exemplar hook was tested by the author in his laboratory and took less than 150 pounds to fail the gate in lateral load, even with the secondary lock properly in place. When inspected by the worker, the hook used daily, appeared to be functional and work proper (Figure 4). This pelican hook was attached (Figure 3) to a 'D' ring type anchorage and is shown (re-enacted) as it started to fail because of the initial stages of roll out of the safety gate. With the safety catch engaged, the load was concentrated directly on the gate at the intersection of the gate and the main frame of the hook. As this gate bent due to overload on the light gage sheet metal components combined with and wear in the hinge joint, it deflected and became disengaged. It could no longer hold the overload. The main frame of the hook then rotated, as shown in the photo, and unhooked from the anchorage. This unhooking caused the worker to unexpectedly slip then fall. Without the pelican hook's positioning support the workers slipped and fell.

The latest, June 30, 2007 Z359.1 ANSI Standard increased the gate load requirement from 350 pounds to 3600 pounds. If a pelican hook built to the 2007 ANSI standard had been used, most likely neither of these roll outs would have occurred. If the pelican hook had not failed and disconnected from the anchorage, a fall that required a separate Fall Arrest System would have been avoided. The statement that the *"hook is designed to allow the worker to work hands free while still being properly attached to a solid anchorage",* was not met since the hooks disengaged and failed to hold the workers in place to work hands free. Both versions of this hook are still in widespread use at actual sites that require fall protection. Projects range from highly regulated nuclear power plants to maintenance on an industrial smokestack.

Summary

These two cases again confirm the pelican type positioning hook must *not be used to prevent a fall* in case of slipping while working in a hazardous location. The reading of that statement often makes no logical sense to the common worker. He has been fitted with a heavy duty body harness including straps, D-rings, lanyards and two heavy duty hooks. He would normally not reason that he must have another fall arrest safety mechanism to keep him from falling. That would require him to use four connections (2 for the lanyards plus 2 for the fall arrest connection) as he moves into position. During tower climbing, speed and safety are often replaced with free climbing which accounts for many accidents yearly.

In each of these two cases each worker, found on the ground, had one of two lanyard pelican hooks with the gate open. This strongly indicates that the hooks were being used and most likely rolled out preceding the free fall. The open hook confirms the hook most likely disengaged from its anchorage. After the fall from the smoke stack other members of the crew also had pelican hooks that indicated similar considerable wear (Figure 5). These hooks were obviously being used but were not suitable for use. The gate would disengage from the main hook with finger pressure at far less than the 350 pounds required even by the earlier standard, thereby rendering the hook even less effective against roll-out while the worker depended on it to prevent a slip preceding a fall.

Figure 5
Gate being deflected with small finger pressure due to wear in parts, but still appears to function as usual.

Conclusion

A false sense of security was implied to the workers; that the very substantial appearance of the positioning hook would hold them safely in position to perform their assigned tasks. Often the workers do not perceive that during normal activities, the positioning hook can shift into a position that it would disconnect by allowing a lateral over-load on the safety gate. This would allow the anchorage point to bypass the hook and let the pelican hook disconnect from the anchorage; followed by an uncontrolled fall. The manufacturers could have prevented these accidents if they had sold the 2007 compliant hooks, the worker's supervisor understood and was assured the pelican hooks met the safety standards. The lateral load requirements changed from 350 pounds in the 1992 standard to 3600 pounds in the 2007 standard. The latest version of the stronger gate protection, most likely would have prevented these two serious accidents (Figure 4). If the positioning hook had not rolled out, but held the worker safely positioned in place, neither of these two falls would have started. Their positioning hook failed each worker, as they worked hands free. Because of the hook failures the falls were inevitable and quickly followed causing serious injuries to the workers.

References

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2. From the manual “INSTRUCTION AND WARNING INFORMATION FOR ALL TITAN HARNESSES, LANYARDS AND BELTS”, 1164 Rev D MFP9720061