“Crane Accidents and Emergencies – Causes, Repairs, and Prevention”

Presented at TOC ASIA 2007 Hong Kong

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March 2007

1. Summary

Crane accidents and emergencies are occurring with increasing frequencies in ports around the world. For example, whereas we, at Portek, used to attend to 4 or 5 crane accident cases a year, we are now attending to more than 12 cases a year. This is understandable due to rapidly increasing population of cranes, increasing crane dimensions resulting in reducing visibility and operator control, frequent adverse weather conditions, and also crane maintenance and operating procedures not keeping up with increasing risks and demands of a fast paced modern terminal. For the sake of brevity, we will limit our discussion to only quay cranes and will exclude yard equipment such as Rubber Tyred Gantry Cranes, Rail Mounted Gantry Cranes and Straddle Carriers.

This paper gives an account of many real life crane accidents and emergencies happening around the world. It studies the causes of these incidents, looks at repair methodologies, and suggests ways of prevention. It further looks at risk management as a whole with respect to crane and terminal operation.

The paper further describes typical actions or procedures to be followed upon the occurrence of a crane incident. These include: survey, salvage and stabilization of the crane; design and structural analysis, repairs and re-commissioning of cranes, and dealings on claims with insurance. Some case studies of typical crane accidents will be presented.

2. Definitions –

2.1 A Crane Accident is an unplanned and un-intentional event involving a crane or cranes, or other objects that result in damage or injury of some kind and normally involves a strong human element in its causation. For example, in a collision between a ship and a crane, the object (the ship or the crane) is under control of an operator and hence there is an immediate human element involved. Such accidents tend to be more often preventable than unpreventable, as the objects (a ship or a crane) in question are under human command and control.

Crane accidents can happen in following ways:

- when a ship contacts a crane
- when a crane contacts a ship
- when cranes contact each other due to strong wind gusts during operation, often resulting in a multiple chain collision
- when a crane contacts another crane or an object during operation
2.2 A Crane Emergency is an unexpected and sudden event in which the crane is subject to damage, and its causation is not immediately linked to the operator. Examples are crane structural failures, crane collapse or structural damage from typhoon or earthquake respectively. More often crane emergencies are not immediately preventable by the crane operator.

Crane emergency situations can arise from

- exceptional situation such as typhoons, hurricanes, earthquakes resulting in crane collapse, derailment or severe damage
- Crane failure as in
  - electrical fires in diesel generator or electrical room
  - crane drive faults leading to free fall of load
  - mechanical faults as in brake failure, twist-locks failures, etc resulting in uncontrolled fall of load
  - structural damage as in fatigue failure, poor workmanship or design.
- heavy weather or inadequate lashing during ocean transportation of cranes
2.3 **Crane Incidents** - For the purpose of convenience, we will use the term “Crane Incidents” as the general term to refer to crane accidents or emergencies. They are normally subjects of insurance claims.

3. **Frequency of Crane Incidents**

Crane Incidents are happening with increasing frequencies in the ports around the world. This is understandable due to:

- rapidly increasing population of cranes
- increasing crane dimensions, hence decreasing visibility and control
- insufficient distance between fender face and seaside rail, and increasing flare of ship’s bow, as ships get bigger
- standards of crane maintenance not keeping up
- standards of safety in crane operation and terminal operation failing to keep up
- insufficient understanding of risks involved, and lack of precautions taken
- more frequent adverse and unpredictable weather

Portek’s assessment of the frequency of Crane Incident occurrence each year would be about 40 cases a year worldwide for damages exceeding USD 200,000 per incident. Based on a worldwide population of 4000 quay cranes, this computes to a probability of about 1 %. Not all such incidents involve insurance claims. Cost of each repairs could be anything from hundreds of thousands USD to 2.0 m USD per crane.

4. **Typical Processes in a Crane Incident**

There are typically 2 phases in any Crane Incident:

- Recovery phase comprising Survey and Salvage and Stabilization – refers to the process of survey and damage assessment, temporary bracing to immediately stabilize the crane to prevent further damage, and isolating operational cranes from the damaged non-operational ones, so as to enable partial operation of the terminal
- Repairs and Re-commissioning – refers to design and analysis, submitting proposals for repairs, obtaining approval from insurance and port authorities, and carrying out of repairs in shortest time possible, conducting checks and testing, and re-commissioning, to return cranes to operation.

4.1 **Recovery Phase:**

4.1.1) **Bracing and Support for Crane Stabilization** - Immediate steps to support cranes facing danger of imminent further instability or collapse. This has to be done immediately usually relying on common sense and sound engineering practices in the absence of detailed analysis. Isolate and contain the damaged crane, so that the berth can continue partial operation.
4.1.2) **Crane Survey** – Immediately after a Crane Incident, surveyors or claim executives appointed by the Ship owner’s insurance or by the Crane Owner (Port Authority / Operator) would have been notified and deployed to site. At the same time, crane specialists like Portek or others would also be called by respective parties to jointly assess damage and to undertake some emergency measures to stabilize subject crane. Damage Survey report would form the basis for various parties involved to reach conclusions as to what actions to be taken.

Visual inspection is usually able to throw up most of the areas in need of repairs. Non Destructive Testing (NDT) may be performed in certain areas if needed. Dimensional checks of the subject crane using theodolite survey instrument, will be able to determine the amount of structural deflection or deformation, and the extent of repairs and correction needed to bring the crane back to required tolerances.

If the subject crane is somehow tangled up with the ship or other objects, then obvious thing is to free up the tangled mess, as it is dangerous to have the ship and the crane bobbing up and down with the tide. Scraps on the quay would be cleared, and damaged crane isolated to facilitate port operation to continue around it

Typical damages would include bending and buckling of the legs, sill beams or derailment seaside and landside, bending of legs (in case of ship colliding with crane legs), buckling of sill beam or portal beam, derailment of bogies, tearing apart of joints between equalizer beam and sill beam.

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**Picture 7:**
Drawings

**Picture 8:**
Contact at seaside leg, only a nick is seen

**Picture 9:**
Derailment at seaside

**Picture 10:**
severe bending of landside leg

**Picture 11:**
No derailment landside, but severe damage to leg
The damage caused by a ship snagging a crane boom (in Boom Down position) is especially vicious. This is due to the fact that the ship catching one end of the crane boom, has a long lever arm to work its havoc on the crane, and it can easily bring the crane down.

4.1.3) Claims and Compensation

The liability pertaining to port equipment, such as a quay crane, comes under Fixed or Floating Object (FFO) Clause of the Ship owner’s Third Party Liability Insurance Policy, which is covered under its Hull and Machinery Policy, or its Protection and Indemnity Insurance.

In some cases, consequential damages resulting from lost production, could be claimable from the Insurance (as in the case of a coal terminal for a power plant in Indonesia)

One may think that in an emergency situation like this, all parties concerned will act expeditiously to come to an agreement on the claim and return damaged crane to operation. In real life, it could take anything from hours, to days or months or even years (if some bureaucratic port authorities are involved) for parties to reach agreement. It is not unusual that Crane Owner (port authorities or operator) would want to claim a higher amount than what the Insurance would be prepared to pay. At times, the Crane Owner may insist on a brand new replacement
crane. The final outcome is a matter of negotiation involving the insurance loss adjusters, and what the Crane Owner is prepared to accept.

In some cases, the crane owner, especially if it is a port authority, may take a hard-line approach by putting the vessel under arrest, especially if the accident involved fatalities. The port may only release the vessel upon the necessary bank guarantee being posted by the ship-owner.

4.2 Repairs –

4.2.1 Design and Analysis – Crane structures are designed to lift vertical loads and can only tolerate certain limited horizontal loads from wind and earthquake conditions. They are not meant to absorb horizontal impact loads resulting from collisions with ship or adjacent cranes. Hence any slight impact from the ship can result in drastic deformation and distortion of the crane portal structures, or a total collapse.

It is often useful to construct, a numerical model of the crane with Finite Element Stress Analysis Software. The impact forces encountered in the accident or collision is simulated and correlated to the real life scenario. This simulation results can be used to help understand the behaviour of the crane structures under impact, and to identify the extent of affected areas, and possible points of failure not seen by the naked eye. It will help us to determine the correct points of support, and to design the correct repair methods, and to improve the crane beyond its original design.

The following diagrams show a bulk unloader experiencing a fatigue failure in the portal beam which leads to buckling in several other parts of the cranes. Computer modeling and analysis was used extensively to re-design the crane structure, and reduce stress levels.

![Fatigue failure of an unloader](Picture16)

**Picture 16:**
Fatigue failure of an unloader

![Computer modeling of crane structures](Picture17)

**Picture 17:**
Computer modeling of crane structures

![Simulation of failure](Picture18)

**Picture 18:**
Simulation of failure

![Redesign and repairs](Picture19)

**Picture 19:**
Redesign and repairs
4.2.2 Crane Supports for Repairs – It is vital to construct the necessary supports for the crane structures to ensure the damaged crane is stable, and to bear the weight of that portion of the crane where repairs are to be carried out. Care should be exercised as a lot of potential energy (associated with elastic deformation) remained locked up in the deformed structures. These structures tend to spring back violently as restraints are removed, causing serious injuries or damage if such spring back is not anticipated.

![Computer simulation of crane support](image1)

**Picture 20:**
Computer simulation of crane support

![Robust support in place before cutting](image2)

**Picture 21:**
Robust support in place before cutting

4.2.3 Repair Methodology – Repairs of the structure normally involve cutting away the damaged plating and this tend to release the locked up energy, and allow the distorted structure to spring back somewhat to its original form. Jacking or heat application may often be needed to get the structures fully back to old form. New plating are then fabricated, and installed.

![Damage plate removed and replaced](image3)

**Picture 22:**
Damage plate removed and replaced

![Damaged sill beam cut away](image4)

**Picture 23:**
Damaged sill beam cut away

![Replaced with new sill beam](image5)

**Picture 24:**
Replaced with new sill beam

Where the bogies remain on rail, one would normally observe damage on the leg which would be subject to severe bending forces, buckling of the box girder would be the result. Where the bogies derail, the leg and sill...
beam would normally sustain little or no damage. Whereas when bogies do not dislodge but stays on rail, the leg or sill beam would normally suffer heavy damage.

For bolted joints construction, it is advisable to replace structural bolts where there is any likelihood of stress.

Damaged mechanisms normally include bogie gears, hinges. Bogies trucks and machineries and balancing beams normally suffer damage as a result of sideway (perpendicular to rail) forces exerted on the leg or sill beams.
Boom damages are often problematic as very often the damaged boom will need to be taken down for repairs and later re-installed. This will necessitate the mobilization of floating crane for removal and re-installation, a costly affair.

Picture 28: Floating crane removing boom for repairs

Picture 29: Re-installing repaired boom

Often, boom hinges may be damaged, and in-situ line-boring will be needed.

Picture 30: Boom hinge inspection and NDT checks

Picture 31: Line boring of boom hinge

Electrical damages would normally be confined to power supply trailing cables being over stretched or broken, or cable reels being crushed. These items have long lead time, and order for new cable would need to be placed immediately to prevent delay of commissioning.

Completion of repairs – Upon completion of repairs, X ray NDT is to be carried out on the welds in the repaired areas, as well as other critical welds just to ensure that hitherto undetected

Dimensional checks – Crane geometry in terms of perpendicularity, diagonality, trueness of hinges are to be checked are to see if within tolerance. In the event that the original tolerance cannot be maintained, then the parties involved can agree on various measures such as additional re-enforcement, or a regime of monitoring crane over a period of time to ensure no deterioration.
Dimensional checks using theodolite equipment

Re-commissioning of cranes: Once the mechanical and structural repairs are completed, the crane will normally be commissioned without too much difficulties.

5. Prevention – Prevention of crane accidents and emergencies can exercised at different levels:

- at crane design and engineering level,
- at crane operating level,
- at terminal operation level.

5.1 Prevention at Crane Design and Engineering level

Gantry brakes – One of the most common wind related accidents is when sudden strong wind gusts act on a crane under operation and propel it along the rail (out of operator control) until it collides with an adjacent crane. It is obvious that rail clamps are not effective in preventing the crane from being pushed out of control, nor are the motor mounted multi-disk brakes, which are inaccessible for servicing, and deteriorate over time. The trend today is to install electro-hydraulic thruster disc brake in each gantry drive (Picture 35). Such thruster disc brake can be selected to give ample braking effect, and should be able to generate sufficient sliding friction between the wheel and the rail to prevent runaway situation.

To provide even more braking power, caliper brakes (Picture 36) acting directly on the idle wheel can be installed, as an added precaution.

Newly built cranes all tend to have double braking systems with each system providing at least 150% of motor torque capacity (Picture 33).

Caliper brakes acting on the flange of boom hoist drums are added as a further precaution (Picture 34).
Double brake machinery

Caliper brakes on flanges of boom hoist drums

Thruster disc brake for gantry instead of motor-mounted multi-disk brake

Caliper brakes on gantry wheel – To provide even more braking power

In ports having strong winds, it is vital that cranes be gantried to designated points to have the storm locking engaged when the crane is not in operation.

Structural cracks – Annual survey visual has to be rigorously carried out. Inspection of internal faces of the girders shall be carried out at longer intervals, and can often throw up many manufacturing faults. Insufficient welding and lack of penetration are common cause of failure.

Usually the load test as witnessed by a professional engineer does not amount to much. It is nothing more than just a formality, and tells us very little about the safety standard of the crane. The crane owner cannot rely on such regulatory certification as it only gives him a false sense of security.

Design of operator cabin, is important with a view to providing good visibility all round, and if there are blind spots, video camera can be installed. A well designed operator cab can reduce operator fatigue, and hence help him to concentrate on his task.

Sufficient lighting to give night visibility is an important point.
5.2 Prevention at the crane operating level,

Safety training of operator cannot be over-emphasized. Emergency drills comprising various steps have to be ingrained into the operator. They should be trained like an airline pilot on how to react in any emergency situation such as, such as free fall of load, crane run-away under wind force, etc. For example, the natural tendency in a crane run-way situation is to drive against the wind. But this only worsens the situation, because when gantry motion is activated, the gantry brake would be open, thus further reducing friction.

Operator must be warned not to find short cuts as in leaving boom down, while not working on a ship. Many a ship snag the crane boom when the crane has its boom down, whereas it should have been ‘boom up’

5.3 Prevention at the port operating level

Berthing and un-berthing of vessels – It is advisable to have the cranes gantried and parked in a safe spot on the quay to minimize chances of contact with ship bow. This is often not practiced in reality due to either too many cranes along the quay, or simply not practiced in the port.

The Port’s Harbour Master should always ensure that harbour tugs deployed should have sufficient power and bollard pull to control the ship’s movement. The ship’s captain and the Port Pilot should try to ensure the ship come alongside the quay as parallel as possible.

The Terminal Manager should ensure that equipment maintenance standards do not get compromised due to busy schedule and Port’s Operations Department not releasing cranes for maintenance.

6. Risk Management Plan

The above prevention techniques can be viewed as part of an overall Risk Management Strategies which a terminal would do well to undertake. Risk management is a process of measuring and assessing risks, and developing a strategy to manage such risks. Amount of risks is defined by the likelihood of occurrence x severity of loss.

Methods of managing risks fall into one or more of following categories:

Terminate the risks – not a likely option for terminals as long as it is engaged in loading and unloading of ships. Lifting equipment is inherently risky, and anything which lies within its load path is potentially vulnerable in the event of a crane incident.

Transfer the risks – Risks can be transferred by taking an insurance policy or by contracting another party to carry out certain functions and to accept the risk. While insurance and outsourcing could transfer away some risks, it could never completely transfer out the risks, because there are consequential losses such as loss of production which is hard to insure, and reputational loss, and loss of lives.

Tolerate the risks – means accepting the risks. Some Crane Owners like Port Authorities may feel themselves to be rather invincible and have good control over any mishaps. Hence, they may opt for Self-Insurance or partially insuring the equipment, whereby the port themselves accept the risks and consequences of crane incidents.

Treating the risks involves reducing the likelihood of occurrence and severity of loss. This is the most sensible form of response to risks. Prevention techniques as described in Section 5 above and taking up necessary insurance policies are part of the Risk Treatment regime.

Adequate insurance for the crane in form of machinery all risks, and requiring all contractors to be sufficiently covered for erection all risks, and public liability insurance.
Terminals should insist that all vessels that call at the terminal should have valid P&I insurance. There was a case of a ship calling a port without P&I coverage, and sank during cargo unloading. The port has to engage salvage to remove the wreck at its own cost, the port had no recourse to the shipping company since it is a one ship company, which became insolvent together with the sinking of the ship.

7. Conclusion

The authors believe that risks associated with container cranes will increase, being under pinned by increasing probability of occurrence and greater severity of loss.

Modern container quay cranes are behemoths of steel and machineries, often produced in a hurry, in some low cost countries. The complexity of such huge and hence highly flexible structures being subject to fatigue loading, and exceptional impact loads are not fully understood yet.

Crane Owners would do well to be more aware of the risks embedded in owning and operating such equipment. There is no substitute for a rigorous Risk Management Scheme that will include stringent safety standards in crane design and manufacturing, day to day operating procedures of the crane and terminal as a whole.

Attached Appendix A (Case Studies)
Appendix A

Case Study A – Port in Europe 2006, Ship contacting crane leg

Flare of ship’s bow making contact is the most common form of “ship contact with crane”. The diagrams and picture below describes an incident in Europe in 2006. The ship in this case hit the left leg inside face (in the direction of gantry travel) and moved the crane along the rail for some distance, causing bending of leg and sill beam. Damage in this case was relatively minor and was confined to only one plane.

Contact at inside face of left leg

No derailment as crane was pushed along rail for 50 m

Leading to buckling on outside face on top

And at bottom face of sill beam

Support the crane with columns and struts to take crane weight

Cut away damaged portion on 3 sides

Cut away damaged plates on 3 sides

Install new plating

Cut away damaged portion and install new plate at the top

Cut off damaged plate at sill beam

Repair of sill beam

Replace keeper plate at rocker joint of bogie

Working at great height

Day and night

Size does not matter, there is room at the top
Case Study B – Port in the Caribbean 2006 - Crane contacting crane under wind force

Strong wind gusts (possibly exceeding 20m/sec) could blow a working crane along the rail and cause it to collide with the adjacent crane often with disastrous outcome. This case study describes an incident in the Caribbean in which a first crane on the right slammed into a second crane (grey color) which in turns pushed a third crane (blue color) against the dead stop. Severe damage was incurred by the second crane portal structure, and the third crane bogies system.

A chain collision of 3 cranes, with 2 cranes inoperable
Tremendous forces knocking off crane buffers
Buffer torn off
Buffer knocked off by dead stop
Landside portal frame parallelogrammed
Buckling of leg plating on 3 sides
Prepared Jacking base
Jacking tower Erected to take weight of landside
Removing damaged sections at both top of leg

Installing new section

New section installed on top

Install strong back after leg straightened

Gantry drive shaft bent

An input shaft is straightened and installed

Bogie hinge to be re-aligned

Elongated bolt holes are rebuilt by welding and re-bored