Incident Summary #II-692974-2018 (#7309) (FINAL)

SUPPORTING INFORMATION	Incident Date		May 19, 2018
	Location		Vancouver, BC
	Regulated industry sector		Amusement Devices - Amusement ride
	Impact – Injury	Qty injuries	0
		Injury description	None
		Injury rating	None
	Impact – Damage	Damage description	Failure of a passenger shoulder restraint system on a roller coaster.
		Damage rating	Moderate
	Incident rating		Moderate
	Incident overview		On May 19, 2018 a passenger shoulder restraint system failed while the ride was in motion, such that the rider was not secured. The passenger completed the ride with no physical injury.
INVESTIGATION CONCLUSIONS	Site, system and components		The ride was approximately 32 years old on the date of incident. The ride is generally known as a corkscrew roller coaster, given the helical shape of the track. Passengers are secured in their seat by a pair of padded bars that cover the shoulders and front torso. The passenger shoulder restraint is held in place with an assembly that includes a threaded trunnion bolt ("trunnion bolt") fastened into the top of a ratchet shaft, Appendix A. The trunnion bolt is fastened by a threaded connection and secured into the ratchet shaft with a jam nut, Figures 1 and 2.
	Failure scenario(s)		The shoulder restraint came loose when the trunnion bolt was pulled out of the ratchet shaft. This occurred under the normal tensile load applied when the shoulder restraint was fastened in place around a passenger during a ride. The passenger was reported to be a female of average size. The normal tensile load, in this instance, was enough to force the male threads out of the threaded female portion of the fitting.
	Facts and evidence		The trunnion bolt had a 3/8 inch diameter NF (national fine) thread. Examination of the trunnion bolt threads found that they were stripped, which may have occurred on or before the time of incident. The incident trunnion bolt was compared to exemplars of other shoulder restraints from the roller coaster and new parts from the original equipment manufacturer (OEM). The incident part was found to have a ball joint casing of a different size and design than the OEM part. The incident part did not bare the original manufacturer's markings or part numbers found stamped in the OEM trunnion bolts. The jam nut of the incident bolt was much larger than the OEM jam nut, Figures 1 and 3. The incident and exemplar components were examined by X-ray. No internal deficiencies were found in the trunnion bolt, ratchet shaft, spring loaded locking pins or other components of the shoulder restraint system. Materials testing verified that

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	the ratchet shaft was made of hardened steel whereas the trunnion bolt was mild steel. Testing found mechanical properties of the incident trunnion bolt to be similar to the OEM bolt. The jam nut used on the incident bolt had 25% less strength and hardness than the original. The OEM had specified that a Grade 8 bolt be used, the incident nut and bolt were found to be a lower strength Grade 2. The corrosion resistant coating had been worn off of the incident jam nut. This jam nut was found to be seized onto the bolt due to oxidation (rust), Figure 4. It may not have been possible to turn the nut to tighten the fastener during routine maintenance checks. It is evident that the trunnion bolt was not in serviceable condition at the time of failure. The bolt threads located above the jam nut were in good condition but heavily worn below the nut, Figure 5. The excessive wear in the lower threads was due to movement of the mild steel bolt against the hardened steel ratchet shaft during ride operation. This movement caused the shaft to abrade the bolt until the crowns of the bolt threads were worn down to the point that the trunnion bolt was no longer securely fastened in the ratchet shaft. Given that the bolt was seized, a torque check may not have detected that that the fastener was loose because the jam nut would feel tight (due to being seized onto bolt). Records show that 12 new trunnion bolts had been purchased in January 2013, enough to replace one quarter (25%) of the 48 seats on the two trains for the corkscrew roller coaster. No further trunnion bolts had been purchased up to the date of the incident. In order for threaded fasteners to remain secure a specific pre-load (torque) must be applied to the bolt and jam nut during installation and must be maintained during the service life of the equipment. Verifying the shoulder restraint bolt tightness should be part of a routine maintenance program for the roller coaster as per the applicable standards. The applicable standard in effect at the time of the incident was CAN/CSA-Z267 *Safety Code for Amusement Rides and Devices*. This standard requires that the ride manufacturer provide torque requirements for fasteners and that the owner/operator inspect, test and maintain the equipment, including preventive maintenance to prevent equipment failure. Following the incident, an investigation was conducted by an engineering firm and a report was issued, dated May 24, 2018. The report recommended replacement of the affected ride hardware with new parts supplied by the manufacturer.
Causes and contributing factors	The incident trunnion bolt failed due to the bolt threads being worn down over time during operation to the point where it was no longer in serviceable condition. The heavily worn bolt threads no longer provided enough contact with the mating threads in the ratchet shaft to resist being pulled out due to normal forces experienced during ride operation. It is likely that the trunnion bolt became loose because the jam nut had seized to the bolt due to oxidation (rust) and could no longer be tightened to keep the bolt securely fastened into the ratchet shaft. A possible contributing factor was the lack of routine preventive maintenance to detect that the bolt had seized and was no longer in serviceable condition.

Photographs

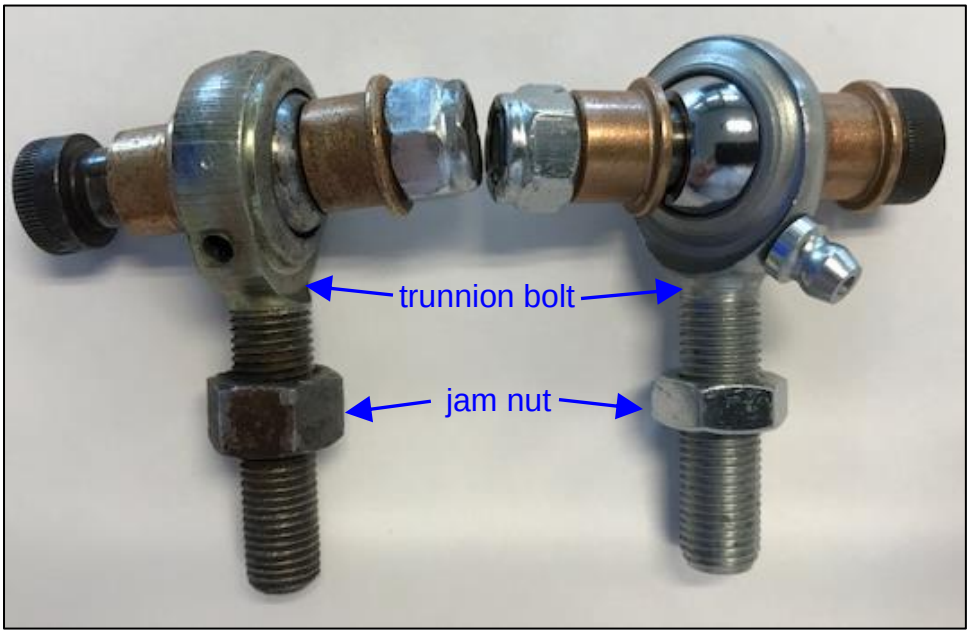

Figure 1: Incident trunnion bolt (left) compared to new part from the original manufacturer (right)

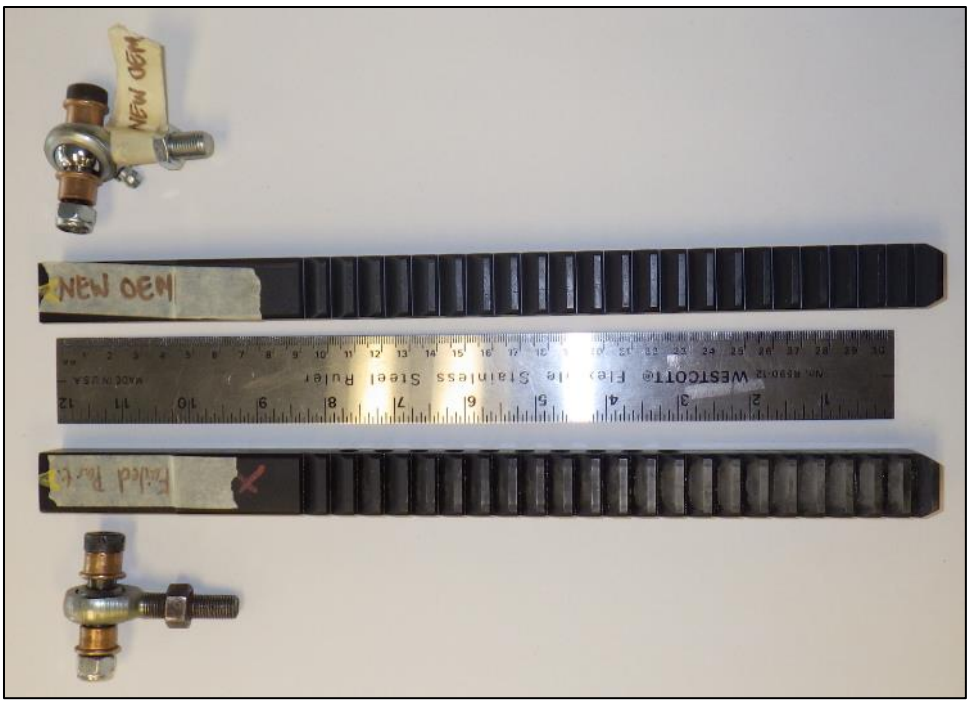

Figure 2: Trunnion bolts and ratchet shafts, incident (below) and new OEM samples (above).

Figure 3: Damaged threads on incident bolt (left), compared to a new bolt (right) and used OEM bolt (centre).

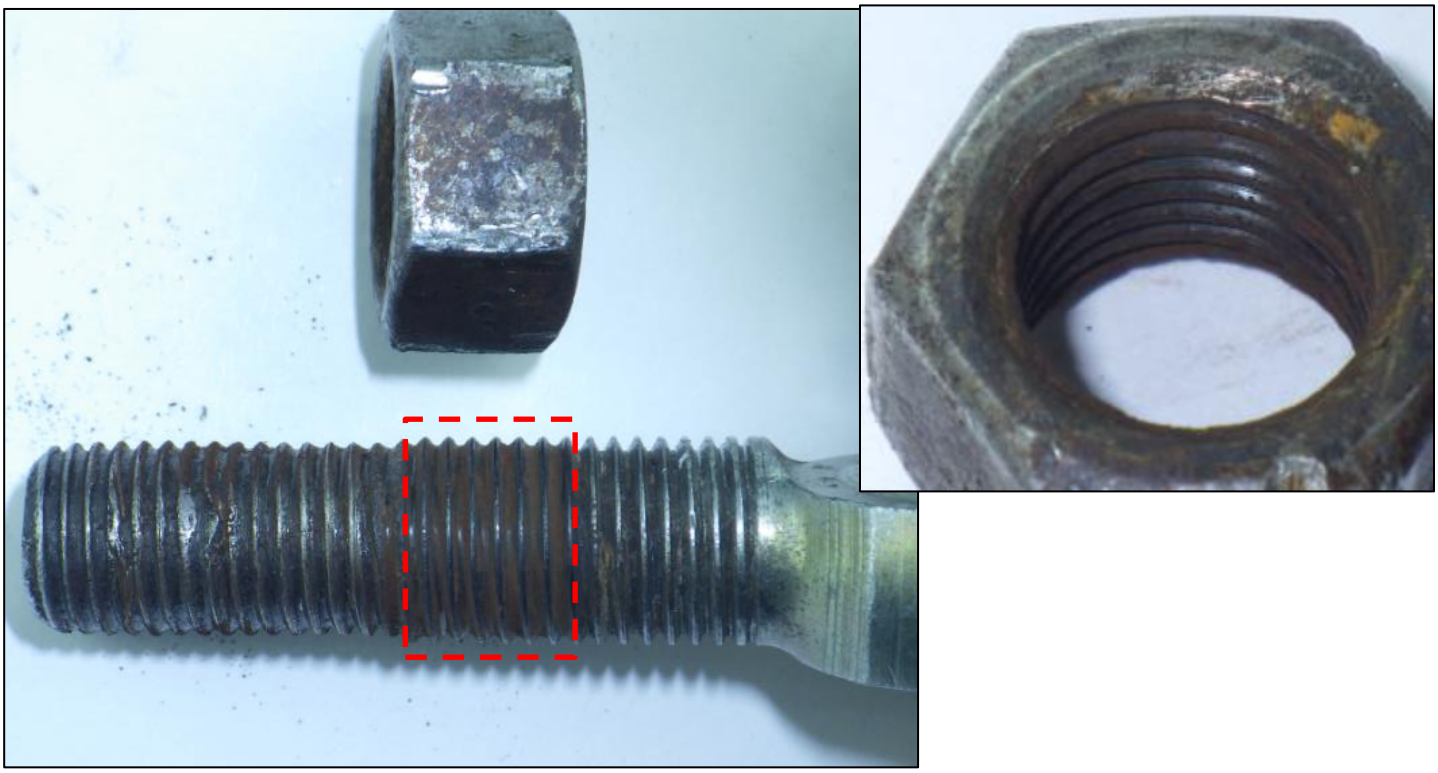

Figure 4: Nut removed showing rust on bolt and nut threads were they were seized together.

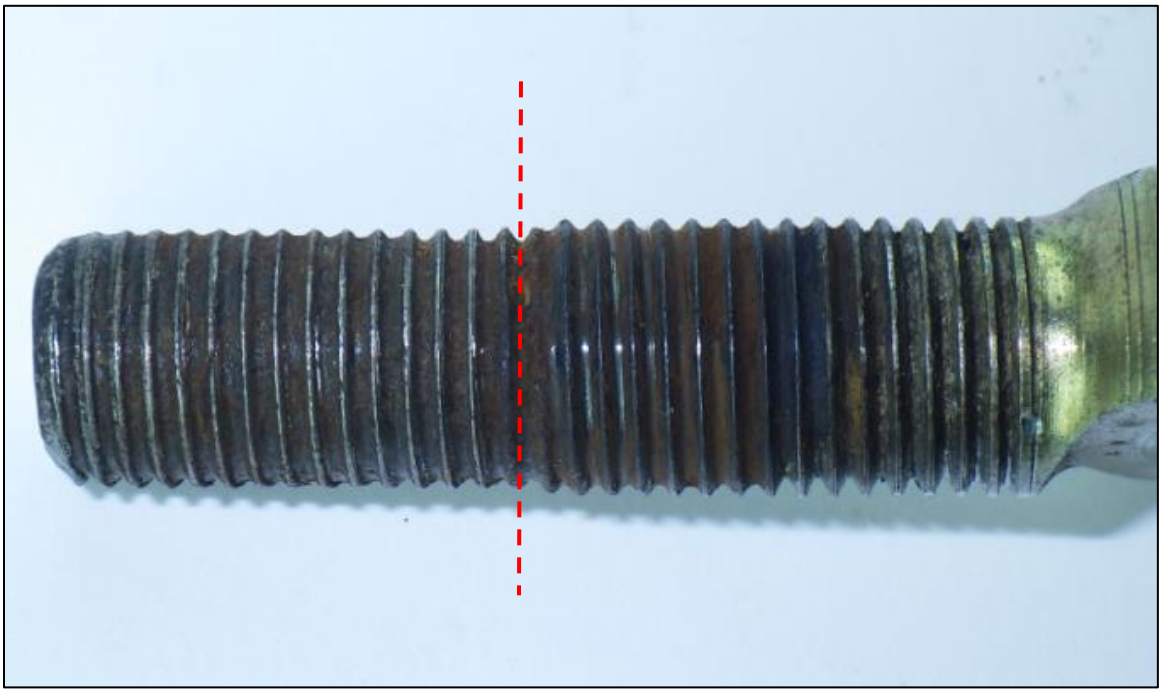

Figure 5: Bolt threads heavily worn, narrowing the bolt diameter below nut position (left of red line)

Appendix A: Ratchet Module Assembly - Restraint Assembly – Corkscrew Ride