General

17.01.2020

The English versions of parts of the investigation report has been translated from Danish by an external translation agency. If there are any disagreements or doubts, the Danish version applies.

Summary

On Wednesday 2 January 2019 at 7:29 am, L 210 (DSB Lyntog 210) collided with a semi-trailer that was blown off G 9233 (DB Cargo Scandinavia's freight train G 9233). The collision took place on the Great Belt Bridge (the West Bridge) close to the abutment on Funen at km 127.440.

At the time of collision, both trains were moving at a speed of approx. 120 km/h.

There were 8 passenger fatalities and 18 passenger casualties at the collision.

The semi-trailer's kingpin was not locked on to the saddle of the freight wagon. The fresh gale that blew across the West Bridge when the freight train passed was therefore able to blow the empty semi-trailer out of its position in the pocket wagon. The semi-trailer was then dragged alongside the wagon until the place of collision.

The first signs that the semi-trailer was lying in the neighbouring track were subsequently found approx. 800 metres before the place of collision in the form of drag marks from the tarpaulin on the top of the protective rails, bits of the superstructure of the semi-trailer and subsequent damage to sleepers and expansion devices.

The investigations have shown that G 9233 was loaded at the combination terminal in Høje Tåstrup on 28 December 2018 and on 2 January 2019 and that the train was inspected – including loading and securing of the trailer in question – independently by several staff members.

The investigations have established that it is not possible to check with certainty that the locks on this type of saddle have been correctly locked and that in some cases the locks on this kind of pocket wagons in service between Høje Tåstrup and Fredericia have not been locked.

It is the assessment of the Danish Accident Investigation Board that video recordings of G 9233 passing several stations and the Great Belt Tunnel show that the semi-trailer on the first pocket wagon was placed in the same position as the other semi-trailers of this type on the train.

Further investigations and tests have established that the wind forces at the West Bridge on the morning in question were sufficient to tip a semi-trailer off of the saddle and pull the kingpin from the saddle on the freight wagon, also when the kingpin was placed correctly in the saddle if the saddle was not locked.

The investigations have also shown that a correctly placed and locked semi-trailer could not be blown from the saddle and wagon by the wind forces mentioned.

The mean wind force measured at the West Bridge did not exceed the limits applicable for freight train traffic on the bridge.

At the time of the accident, the Great Belt Bridge was closed for road traffic due to the wind forces measured at the East Bridge (the High Bridge).

Based on the investigations, it is concluded that it is highly probable that the semi-trailer was loaded correctly with the kingpin placed in the saddle, but that the lock that was to secure the semi-trailer to the pocket wagon was not working correctly, meaning that the semi-trailer was thus not locked on to the pocket wagon.

The IC4 train set has been examined to assess its crashworthiness. The conclusion is that the coach body of the first coach was exposed to impacts beyond the design requirements for the train type. The design of the coach body with double-sided extruded aluminium profiles has exerted a braking influence on the driving-direction motion of the semi-trailer, thus having a protective effect when exposed to the extensive force from the semi-trailer. This means that the design has in all probability limited the damage to the first wagon and thus also limited the number of fatalities and casualties.

Despite the fact that the deceleration in this collision was relatively limited, many lighting panels had dropped out of their fixtures on the underside of the luggage racks. These lighting panels have sharp corners and edges that have the potential of inflicting injuries on persons, but there is no information as to whether any passengers in L 210 were injured by falling lighting panels.

The Accident Investigation Board has provided the following recommendations:

Recommendation 1

The Accident Investigation Board recommends that ERA ensures that all safety-critical equipment (such as accessories) on freight wagons is identified and addressed in the European maintenance regime.

Recommendation 2

The Accident Investigation Board recommends that the Danish Transport, Construction and Housing Authority ensures that, going forward, the safety management system of DB Cargo Scandinavia A/S collects safety-relevant knowledge from staff members and other involved parties and that the company’s safety management system addresses any such information.

Recommendation 3

The Accident Investigation Board recommends that the Danish Transport, Construction and Housing Authority ensures that Banedanmark and A/S Storebælt carry out an analysis of the need for updated safety requirements with regard to wind restrictions and the quality of wind measurements and make sure that among other the storm emergency team is aware of the safety threshold values.

Recommendation 4

The Accident Investigation Board recommends that the Danish Transport, Construction and Housing Authority ensures that DSB looks into the possibility of improving the fastening of lighting panels on the MG class (the IC4 train type) and implements the improvements to the necessary extent.

The recommendations are available in full in section 7.

Analysis

Sequence of events

The semi-trailer from the first pocket wagon in G 9233 collided with the front of L 210 on the Great Belt Bridge (West Bridge) at approximately km 127.440 of the section (about 400 metres from the abutment on the island of Funen).

The accident took place at 7:29 in the morning before daylight.

Video recordings and evidence (clues?) from the bridge showed that the semi-trailer had overturned from the freight train at least 500 metres before the collision and was lodged on the side of the pocket wagon until at least 300 metres before the collision. Finds in the empty pocket wagon of parts from the front of the IC4 train set showed that the semi-trailer was fully or partly on the side of the first pocket wagon at the time of the collision with L 210.

Damage to the track and finds of trailer parts showed that the semi-trailer's superstructure was in contact with the south track at about km 126.646. The semi-trailer is therefore deemed to have partly overturned from the pocket wagon at least 800 metres before the point of collision at km 127.440.

Marks on the tarpaulin from the left side of the semi-trailer and marks on the top of the protective rails show that, prior to the collision, the semi-trailer had tipped more than 90 degrees in relation to the normal position of the pocket wagon and had been dragged across the south track/neighbouring track.

The damage to the semi-trailer's stabilizers and to the pocket wagon's container bar indicated that the semi-trailer's left stabilizer had caught in the front container bar by the time of the collision.

The investigations into why and how the semi-trailer was able to leave its position in the pocket wagon and collide with L 210 gave rise to three possible scenarios:

a) The semi-trailer was correctly loaded with the kingpin locked securely in the saddle.
b) The semi-trailer was loaded with the kingpin in front of or behind the saddle.
c) The semi-trailer was loaded with the kingpin in the saddle, but the saddle was not locked.

a) <u>Semi-trailer correctly loaded with the kingpin locked securely in the saddle</u>

Attempts to pull the kingpin vertically out of the correctly locked saddle showed that the kingpin could not readily be pulled clear of the saddle; instead, the wagon started to lift clear of the track.

The second semi-trailer on the same pocket wagon as the trailer involved in the accident was almost empty, but locked in the saddle and remained in position on the pocket wagon.

The eventuality of the rear end of the semi-trailer having been blown out across the pocket, with the kingpin lodged in the saddle, seems unlikely considering the torsional stability that exists in the welded construction on this kind of semi-trailer according to the manufacturer. The tensile test confirmed that the semi-trailer was relatively rigid. The weight distribution on an empty semi-trailer was approximately 5 tonnes on the axles and 1.5 tonnes on the kingpin.

The finds showing that the semi-trailer was suspended across the neighbouring track and dragged along indicate that the semi-trailer was lying on its side, tilted at more than 90 degrees to its position on the pocket wagon, that virtually the entire length of the left side-tarpaulin had been dragged across the neighbouring track and that the top left corner had hit the track (partly at the point of the expansion device).

No damage was found to the saddle and lock, or to the pocket wagon, respectively, suggesting that the semi-trailer would have been hanging by its kingpin with the rear end twisted and lifted out of the pocket.

The way the semi-trailer penetrated the front of L 210 shows that at that point it was clear of the saddle and cannot have been torn clear of the lock at that juncture.

In a derailment incident in Sweden in February 2019 it was observed that pocket wagons were able to overturn, while semi-trailers still remained secured to the pocket wagons.

Winds like those occurring at the time and place of the accident would not be capable of blowing the semi-trailer clear of the saddle and pocket wagon if locked in the saddle.

Based on the available evidence, it can be established that the semi-trailer was not correctly locked to the saddle.

b) Semi-trailer loaded with the kingpin in front of or behind the saddle

Both before and since the accident there have been examples of semi-trailers being transported on pocket wagons without the kingpin being positioned in the saddle. Basically, this scenario is not unrealistic, but there are factors that militate against it in this instance.

During and after loading it was ensured that the semi-trailer was correctly loaded. Independently of each other, two crew members carried out checks to ensure that the semi-trailer was in position with the kingpin in the saddle. Owing to the previous events referred to above, making sure that the kingpin was in the saddle was a focus of attention.

Tensile testing showed that if the semi-trailer had been loaded with the kingpin in front on the left or behind the saddle, it would have required less of a wind force than occurred on the day of the accident to thrust the trailer out of profile.

From Høje Taastrup the freight train had travelled across Zealand to the Great Belt in an east-west direction, where the direction of the wind was north-south. Video recordings from the Great Belt Tunnel and from platforms showed no signs that the semi-trailer was out of profile before the train arrived at the low bridge.

Tests with the kingpin loaded in front of the saddle showed that the kingpin was able to get lodged in a part of the saddle until the traction became sufficiently powerful. The test resulted in damage to both kingpin and saddle, the equivalent of which was not found on those parts that were involved in the accident.

Furthermore, the front end of the semi-trailer would have been expected to slide out and the stabilizer to have damaged the inside of the pocket wagon. There was no damage to the inside of the pocket wagon other than that due to normal operations.

c) Semi-trailer loaded with the kingpin in the saddle, but saddle not locked

When the saddle was inspected after the accident, the levers were ascertainably and completely in the locked position.

The tests carried out by the Danish Accident Investigation Board, pulling the kingpin up from the saddle, showed that the saddle went into the locked position when the kingpin was pulled up. The above does not, therefore, preclude the possibility that the saddle may have been unlocked in transit. The forensic investigations confirmed that the saddle did not lock unaided during loading due to sluggishness of the lock mechanism.

An additional two saddles were found that were not locked on the freight train involved in the accident. At these sites were loaded semi-trailers that were at least three times heavier (and hence less sensitive to wind) than the one that toppled off the freight train. Investigations into other freight trains showed that, here too, there were saddles that were not locked. The problem with unlocked saddles therefore seems to have been widespread at the time of the accident.

Tensile testing showed that there was sufficient clearance between the hole in the saddle and the kingpin to allow the kingpin to be pulled up when the semi-trailer was overturned.

Forces measured during tensile tests, compared with data from wind tunnel tests, showed a clear correlation, confirming that the scenario was realistic.

The tests showed that, at a train speed of 120 kph, a wind force of 20 m/s would be sufficient to overturn the semi-trailer from the pocket wagon. At the time of the accident the mean wind force was about 20 m/s with gusts of up to 21.6 m/s.

Safety provisions

The traffic restrictions set out in the safety provisions were based on mean winds, not maximum gusts. The relationship between mean wind and gusts is not a constant, so the mean wind was not necessarily a satisfactory indication of the concrete impact of the wind. The limit for (speed) restrictions for rail traffic was 21 m/s, and since the mean wind was less than 21 m/s, there were no speed restrictions at the time of the accident.

It should be noted that the safety provisions generally assume that goods on freight trains are properly loaded and secured.

Saddle design

The reason the saddle did not automatically lock sufficiently was traced to inertia in the movement of the release lever, as well as connected levers with pivot points (primarily release lever and bush).

There were two sets of design drawings for the bush and the release lever. The first drawings received described greater tolerances that potentially failed to leave any clearance between the external bush diameter and the release lever. The drawings most recently forwarded described modified tolerances, which resulted in a minimum of 0.25 mm clearance between the external diameter of the bush and the bore diameter of the release lever.

A survey of the bush and the release lever's bore diameter showed that they conformed to the earlier design but not to the most recent one. The clearance measured between release lever and bush was 0.1 mm, and they had corroded together.

The design of the saddle did not allow effective lubrication with grease at the pivot point for the release lever without disconnecting the saddle. The manufacturer's manual described lubrication every four months with lithium-based grease. It also placed special emphasis on "all parts of the lock mechanism".

However, the illustration in the manual did not indicate any of the movable parts under the saddle plate; and since these could not be lubricated effectively using grease, lubricating the hole in the kingpin, together with the lock parts fitted inside, could be taken to be sufficient.

The maker's procedure for loading and locking the saddle was described in the operating manual. The description in the manual could be read in such a way that when the cutout in the control lever was not visible, the saddle would be locked. Investigations of the saddle have shown that the saddle risked not being locked even when the cutout was not visible.

Maintenance

There is no known documentation to show periodic maintenance and inspection of the saddle between pocket wagon overhauls.

The bottom of the saddle plate, with movable parts, clearly showed traces of a failure to lubricate. Conversely, the hole in the kingpin was well lubricated.

The saddle plate was worn and defective. The edges of the hole in the saddle plate to the guide ring were deformed, preventing the guide ring from sliding freely to such an extent as to make it impossible for the automatic emergency braking system to function optimally. The emergency braking system is only of importance during major semi-trailer movements longitudinally and therefore had no bearing on the accident sequence.

The task of lubricating all the lock mechanism's movable parts has not been clearly identified and placed.

Descriptions from the saddle manufacturer do not feature detailed illustrations and are inadequate if the task is presumed to be carried out when operational. If the job of lubrication is presumed to be carried out at a certified workshop with qualified staff (meaning trained staff here), the descriptions may be adequate.

No correspondence is seen between scheduled times for the pocket wagon servicing regime and the times laid down in the saddle operating and maintenance manual.

Lubrication of the saddle's movable parts is not regarded as regular maintenance of neither the ECM unit, or the keeper or the railway undertaking, in spite of the manufacturer stating outright in all versions of the maintenance manual that non-lubrication may be critical to safety.

It is the Accident Investigation Board's assessment that lubrication of the saddle must be accorded the same status as regular maintenance.

There is no evidence that correct lubrication of the saddle's movable parts, including the lock mechanism, was regularly checked in accordance with the manufacturer's instructions.

At the time of the accident there was no documentation of regular inspection and maintenance of the saddle or lubrication of the lock mechanism's movable parts on the saddle.

Different versions of the saddle operating and maintenance manual have been received from the workshop, operator and saddle manufacturer.

The overriding conclusion is that insufficient attention has been paid to how, and by whom, the movable parts on the saddle's lock mechanism are to be lubricated. If this lubrication has not been correctly performed, the saddle manufacturer states that such failure to lubricate may be of significance to safety, and thus that the lock mechanism risks not being serviceable, and hence the semi-trailer is not locked to the pocket wagon.

Crew members working on loading, unloading and repairing of saddles have expressed the view that lubricating the saddle is not viewed or characterized as being critical to safety, and they regarded lubrication as an operational task.

Design and conditions for use

The pocket wagon was designed with a view to eliminate the need for multiple anchor points, thus making the saddle's lock mechanism and the kingpin the only anchor point between the pocket wagon and the semi-trailer. This in itself makes the saddle a safety-critical point meriting special attention. In the event of a failure, the only other barrier is that the lock on the saddle can be checked after loading a semi-trailer.

Focusing on the fact that the saddle is the only anchor point, and on descriptions of risks associated with non-lubrication given by the saddle manufacturer in their instructions, lubrication should be regarded as safety maintenance and be documented. This cannot be equated with lubrication of e.g. a buffer or with cleaning.

Labels and panels on the pocket wagon were updated after the pocket wagon was modified in the form of a raised wagon bed. A 't' is missing for correct codification.

The instructions can be misleading, as it is not clear when the codification on the semi-trailer should be followed and what exactly applies in what instance.

Approvals

The original approval of the pocket wagon has been documented and is transparent. No irregularities have been noted.

The increased height of the pocket wagon bed had not been approved. At the time it was modified, the modification did not necessarily have to be approved by the authorities but could be dealt with in-house at the relevant rail company if it was able to prove that the modification was a minor one. No documentation for such reasoning has been found. It has not been possible to get hold of working descriptions or drawings relating to the "raised wagon bed".

Broadly speaking, documentation of the modification was limited to conclusions, though to some extent assessments were described in conjunction with the modification.

No notifications were issued to the authority (the Dutch safety authority) that had issued the approvals.

The Danish Transport Authority (National Rail Authority) was aware of the modification.

When VTG Rail Europe GmbH was certified as an ECM unit, no shortcomings were identified in their procedure for identifying and controlling all maintenance activities impacting on safety-critical components ((EU) 445/2011, Annex II, Article II.1).

Loading regulations/servicing

The operator's loading regulations were based on the maker's manual, which described how the saddle was locked when the operating levers were pulled in completely and the cutout on the operating lever was not visible. The manual did not describe how to be sure that the operating lever was in the fully retracted position and contained no further inspection requirements.

At the time of the accident the loading regulations required inspection of the saddle, but no function check prior to loading, nor any additional check after loading to see whether the saddle was locked apart from the above.

The loading regulations described how the stabilizers on the semi-trailer had to be moved upwards after loading and before transit. Measurements subsequently showed that the stabilizers could not have touched the wagon bed and were clear of the wagon bed as they were meant to be.

Raised wagon bed

Because the operator was moving mega semi-trailers, the wagon bed had been raised by 155 mm where the wheels of the semi-trailer were. At the same time, the saddle had been adjusted to its highest setting (1,130 mm) for semi-trailers, which would normally be transported in the centremost setting (980 mm). Since the whole upper part of the semi-trailer was already above the pocket at all settings, the 155 mm only meant that the wheels were exposed more to the wind.

The raised wagon bed may have resulted in the semi-trailer tipping out over the side of the pocket wagon more easily. However, the sides of the pocket are not considered high enough to prevent the semi-trailer from overturning, but were primarily designed to prevent skidding.

Against the backdrop of the above, it is considered that the raised wagon bed had no or very little influence on the accident, though this has not been investigated in more detail.

Other saddles

The saddle that had been placed in position 3 was in such a poor state that the lock mechanism was completely immovable.

In as far as it was ascertained that the freight train from the accident had a further two saddles which were not locked and another train had two saddles which did not lock, and crew members who unloaded and loaded the trailers were aware that the fault was not atypical on saddle locks prior to 02.01.2019, unlocked saddles in operation can only be found to have been a known fault at the time of the accident.

Other factors

The fact that the engine driver in L 210 opted to drive 120 kph when he was allowed to drive 180 kph probably reduced the consequences of the collision.

In its investigations DTU deemed the wind speed measurements to be valid. The supplier of the meters has stated that the individual wind meter may offer a less precise measurement in any one particular wind direction.

Restrictions in connection with wind impacts have been altered several times. The existing restrictions were stipulated on the basis of harmonization with threshold values in a “management process” at Banedanmark (Rail Net Denmark), dictating that a three-level storm contingency plan be set up. These threshold values, with which the threshold values on the Great Belt have been harmonized, apply throughout Denmark and largely have to do with regularity and fallen trees.

There is nothing in the crashworthiness investigation to indicate that there were inadequacies or faults in the train’s coach body design or manufacture. With regard to the interior, a number of lighting panels on the underside of luggage racks fell down despite the limited deceleration.

Conclusion

Based on the investigations carried out, it is the assessment of the Accident Investigation Board that the only likely scenario is that the semi-trailer was loaded with the kingpin in the saddle, but that the saddle was not locked before the accident.

It is the opinion of the Accident Investigation Board that the unlocked locking mechanism was the reason the empty and thus relatively light semi-trailer could be blown from its place in the freight train and collide with L 210.

At the time of the accident the mean wind speed was registered at below 21 m/s and thus below the applicable limits for introducing restrictions on rail traffic across the Great Belt (the West Bridge).

The Accident Investigation Board finds that the following factors had or could have had an impact on the inadequate locking of this as well as other similar saddles where investigations have established that they did not lock correctly:

- The common European maintenance regime (GCU) implied that the maintenance of the actual freight wagon was found to be satisfactory, but the safety maintenance of the parts regarded as "accessories" were not included in the scheduled maintenance.
- All editions of the saddle manufacturer's manual identified lubrication of the saddle as safety-critical, but this knowledge was not identified by the operator's safety management system and was not part of the scheduled maintenance of the saddle.
- The saddle design made it difficult to lubricate the pivot of the release lever, and the previous design did not leave sufficient clearance between the release lever and the bush.
- The design of the saddle impeded the lubrication of other pivots in the rod mechanisms on the back of the saddle plate.
- The manual of the saddle manufacturer included maintenance instructions that did not clearly describe the necessary lubrication of the movable parts below the saddle plate.
- The maintenance of saddles was generally characterised by shortcomings.
- The manual of the saddle manufacturer described that the saddle was locked when the lever was pulled back fully and the cutout on the control lever was not visible. The Accident Investigation Board's investigations have shown that the saddle could be unlocked even when the control lever was pushed in and the cutout was not visible. It was not possible to verify visually that the lever was fully pulled back.
- At the time of the accident, the operator's loading instructions did not include any functional check of the saddle before loading, which was not a requirement.
- The operator's checking of the saddle being locked when a semi-trailer was loaded was based on the manufacturer's manual. This check based on the manufacturer's manual was not sufficient to ensure that the saddle was locked.

- It is the responsibility of the Entity in Charge of Maintenance (ECM) to prepare maintenance plans in accordance with the manufacturer's recommendations, paying particular attention to safety-critical activities. This raises further questions to the certification of the particular ECM as to whether any weaknesses have been identified in VTG Rail Europe's procedure to identify and manage all maintenance activities which affect safety-critical components.
- The measurements of the wind speeds from the two anemometers have been assessed as valid. There may be some doubt as to whether one of the anemometers might measure less accurately at certain wind directions and there may therefore be some doubt as to the overall quality of the wind measurements.

Investigations of the crashworthiness of the IC4 train set did not establish any fault in the coach body of the train set, but they did point out a possibility for improvement with regard to the interior of the train type.

Supplementary information

The crashworthiness specialists have pointed out that, going forward, it should be considered whether requirements should be made with regard to penetration resistance for the coach body walls similar to the requirements made on the roof structures of the coach body when designing new trains.

Safety recommendations

Recommendation 1

The existing maintenance regime, which is managed through the GCU contracts, appears to function well in relation to the actual freight wagon type. However, with regard to components that may be described as “accessories”, safety-critical maintenance (e.g. correct lubrication of the saddle) appears not to have been identified and addressed.

DK-2019 R 1 of 18.12.2019

The Accident Investigation Board recommends that ERA ensures that all safety-critical equipment (such as accessories) on freight wagons is identified and addressed in the European maintenance regime.

Recommendation 2

The issue that a number of the locks on the saddles were not working is a fact of which some of the staff members at DB Cargo Scandinavia A/S and Carlsberg, who load and unload semi-trailers, were well aware. This knowledge appears not to have been identified or addressed in the safety management system of DB Cargo Scandinavia A/S.

DK-2019 R 2 of 18.12.2019

The Accident Investigation Board recommends that the Danish Transport, Construction and Housing Authority ensures that, going forward, the safety management system of DB Cargo Scandinavia A/S collects safety-relevant knowledge from staff members and other involved parties and that the company’s safety management system addresses any such information.

Recommendation 3

Restrictions in connection with wind effects have been changed several times. The existing restrictions appear to have been established based on a harmonisation with the threshold values in a “management process” in Banedanmark that requires the establishment of a three-level storm contingency plan. These threshold values, with which the threshold values on the Great Belt are harmonised, apply to the entire country and concern largely regularity and fallen trees.

DK-2019 R 3 of 18.12.2019

The Accident Investigation Board recommends that the Danish Transport, Construction and Housing Authority ensures that Banedanmark and A/S Storebælt carry out an analysis of the need for updated safety requirements with regard to wind restrictions and the quality of wind measurements and make sure that among other the storm emergency team is aware of the safety threshold values.

Recommendation 4

Despite the fact that the deceleration in this collision was relatively limited, many lighting panels had dropped out of their fixtures on the underside of the luggage racks. These lighting panels have sharp corners and edges that have the potential of inflicting injuries on persons.

DK-2019 R 4 of 18.12.2019

The Accident Investigation Board recommends that the Danish Transport, Construction and Housing Authority ensures that DSB looks into the possibility of improving the fastening of lighting panels on the MG class (the IC4 train type) and implements the improvements to the necessary extent.