Case Study 9

MSC CARLA

Complete Hull Failure in a Lengthened Container Vessel

Vessel Particulars

LOA: 289.5 m
Breadth: 32.21 m
Depth: 23.9 m
Draft: 11.9 m
Gross Tonnage: 55,241
Deadweight: 40,912 tonnes
Container Capacity: 2870 TEU
Design Speed: 23 knots
Builder: Gotaverken OresundVarvet A/S, Lanskrona, Sweden
Year Built: 1972
Lengthened: Hyundai Mipo Dockyard, Mipo, South Korea, 1984
ID No.: 7214624
Class: Lloyds Register
Flag: Panama
Registered Owner: Rationis Enterprises, Inc., Panama
Charterer: Mediterranean Shipping Co., Geneva
Vessel Type: Double hull containership, Triple screw diesel propulsion
Hull Material: High Strength Steel
Arrangement: 12w x 3h above deck, 10w x 8h below, 8 holds

Figure 1. Profile of MSC CARLA

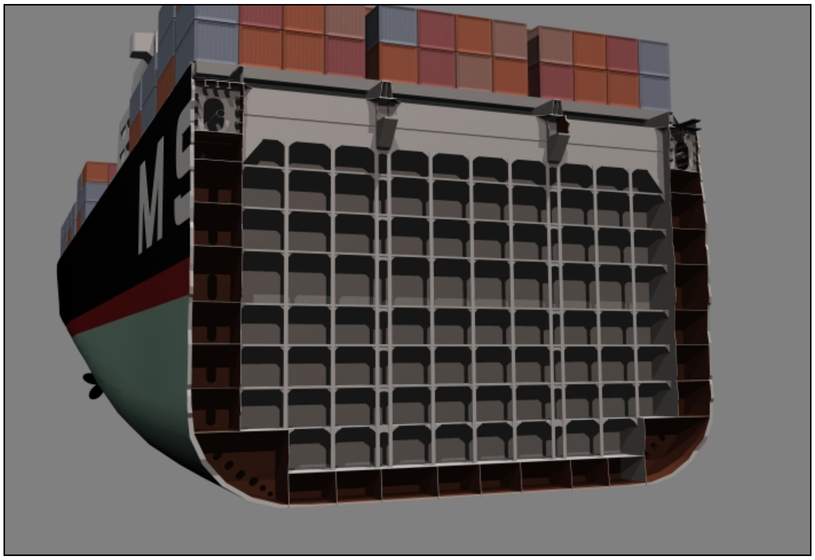

Figure 2. Section of MSC CARLA

Summary of Structural Failure

The hull of MSC CARLA broke apart at the forward end of the new midbody. The bow portion sank after five days. The stern was towed into port.

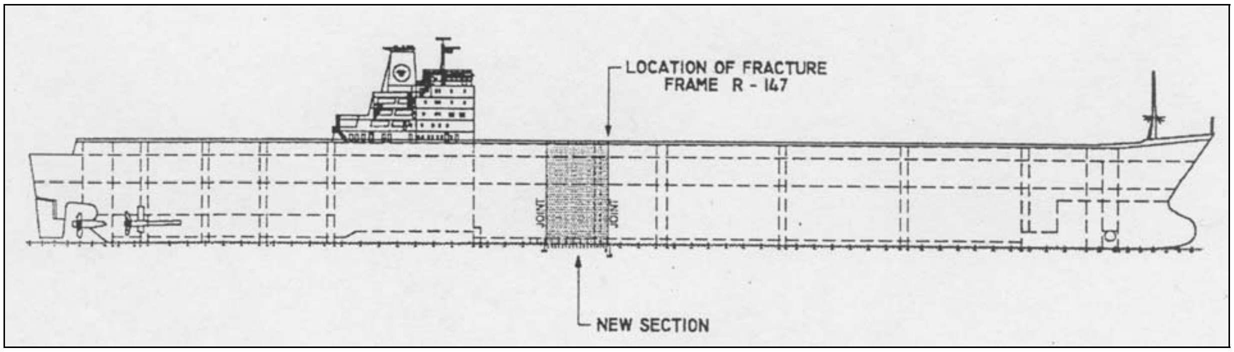

Figure 3. Location of Midbody and Fracture

Background

Lengthening

MSC CARLA was built in 1972 in Lanskrona, Sweden. She was originally 275.22m LOA. In 1984 she was lengthened by Hyundai Mipo Dockyard to 289.48m, an addition of 14.27m. This was accomplished by splitting the hull between frames 146 and 147, in Cargo Hold 5 – the first hold forward of the house – and inserting a section 15.06m that included 22 frames and one transverse bulkhead. (The bulwark at the bow was shortened, resulting in the net change of 14.27m.) The additional midbody created a new 40' container hold below deck.

In order to enhance the longitudinal strength of the lengthened vessel, straps of plating were added on the main deck in way of the box girders at either side. These straps were 650mm wide by 45mm thick and welded with 21mm filet welds. There were three straps on each side, extending from frame 114 to 219 outboard, frame 118 to 171 in the middle, and frame 122 to 160 inboard.

Events leading to failure

MSC CARLA departed La Havre, France for Boston on 21 November 1997, fully loaded with 21,171 tonnes of containers (2392 TEU). She had recently completed her 25 year special survey for Lloyds Register and the master reported her being in optimum condition. On 24 November 1997, when MSC CARLA was 125 nm, NE of Azores, weather conditions become poor with winds up to 70 miles per hour and seas over 11 meters. Seas were from the starboard bow, with swells from a previous storm from the port bow. At 1800, the vessel experienced several severe rolls, causing items in the deckhouse to be tossed around and all three engines to fail. The engineer was able to revive the center engine and the vessel continued on course but at reduced speed.

At approximately 1830, MSC CARLA encountered two very large steep waves. As the vessel was climbing the first wave, the master noticed that the light on the bow was not where he would expect relative to the rest of the ship. Coming down the back of this wave, the vessel made a "strange motion" and there was a loud noise. As the ship climbed the second wave, the bow separated to the port side. The captain was able to steer the stern to starboard to avoid striking the bow.

The bow floated for five days before sinking. The stern was towed to the Canary Islands to offload cargo, and then back to Gijon, Spain where it was scrapped.

Detailed Description of Structural Failure

MSC CARLA broke cleanly through the shell plate between frames R and 147 – the forward end of the new midbody. Because the stern of the vessel survived the casualty, substantial forensic evidence was available to experts to ascertain the mechanics of the failure. Because of the location of the fracture, the midbody addition was immediately suspect. Forensic analysis identified both design and manufacturing defects that contributed to the failure of MSC CARLA.

Design Defects

Six doubler straps (three port, three stbd) were added at the main deck over the box girders to increase the section modulus of the midship section to compensate for the increase in length. Minimum required section modulus in ABS is a function of length squared. With the increase in length of 14.27m over 275.22m or 5.2 percent, the increase in required section modulus is 10.6 percent. There are several aspects of the doubler design that acted to diminish their effectiveness.

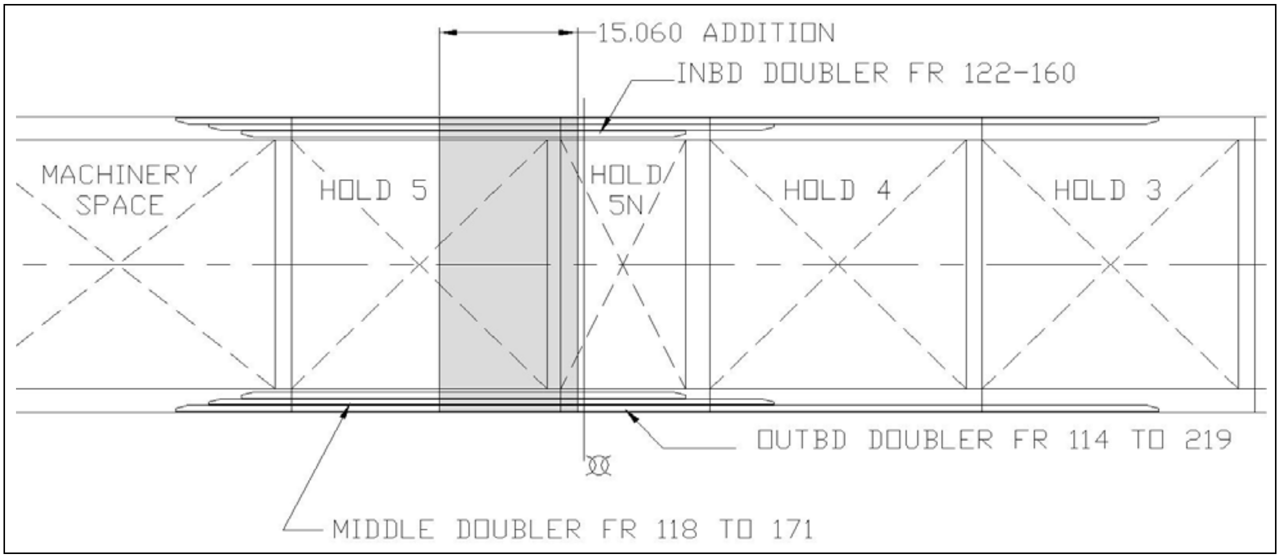

Figure 4. Plan View, Main Deck

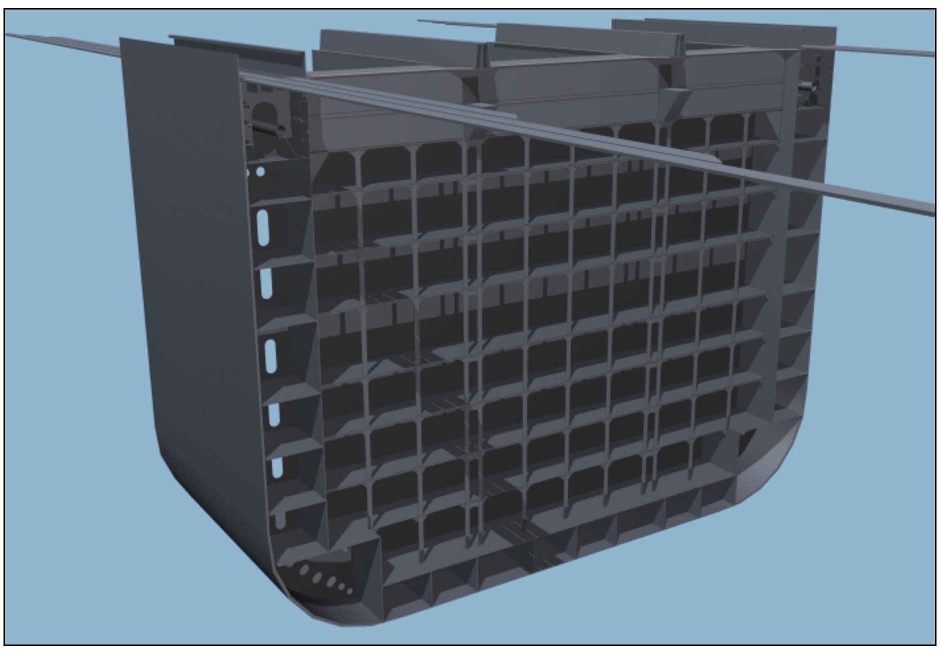

Figure 5. New Midbody and Straps

The doubler straps were designed as 650mm wide by 45mm thick and attached by 21mm filet welds. Both ABS and Lloyds caution against using doubling that is excessively thick relative to the thickness of the existing plate. ABS advises limiting doubler material to 1.25 times the existing plate, but stipulates that 1.5 may be allowed in isolated cases. They warn that the situations where they have seen ratios up to 1.5, results have not been favorable. Specifically, cracking has occurred in way of the butt joints. Lloyds limits doubler material to 2 times the existing plate, but their experience was limited to ratios of 1.25 times. On MSC CARLA the existing deck plating was 33mm in way of the joint and as thin as 30mm within the length of the doubler straps. The corresponding thickness ratios are 1.36 and 1.5, respectively, within the limits of ABS and Lloyds but outside the bounds of their favorable experience.

Lloyds recommends the breadth to thickness ratio of doublers not exceed 15. At 650mm by 45mm, the straps on the MSC CARLA have a ratio of 14.4. In Lloyds' technical bulletin on the subject, their case studies were limited to doublers less than 550mm wide and only three cases were considered that were over 450mm. ABS recommends a maximum doubler width of 574mm without the use of plug welds. There were no plug welds used on the MSC CARLA.

Manufacturing Defects

Even in areas where the straps were designed appropriately, they were not necessarily installed according to the Lloyds approved plans.

Because of the long length of the doubler straps, butt welds were necessary to make up the length. These welds were to be full penetration to maximize the strength of the joint. Had these connections been made in the shop, it would have been possible for the full penetration to have been accomplished by welding from each side of the plate. Instead, the plates were joined on the ship, making the full penetration impossible.

In order to mitigate any weakness of these joints, it was specifically called out on the drawings that butt welds in the doublers be at least 1m away from the butt welds in the deck plates. When installed this was not adhered to, resulting in a common joint were both the deck and doubler are welded in the same location.

The deck plate in the existing ship was 30mm, while the deck plate in the new midbody was 33mm. In order to provide a flush surface for the doubler straps to land on, the new deck was to be flush above deck with the additional thickness below.

Butt welds in the doublers were to be full penetration and as such the edges were beveled. When the beveled edges were aligned on the ship, their geometry with the thicker deck plate is such that the effective thickness of the doubler is reduced. This occurs in an area of high stress due to the overlapping butt welds.

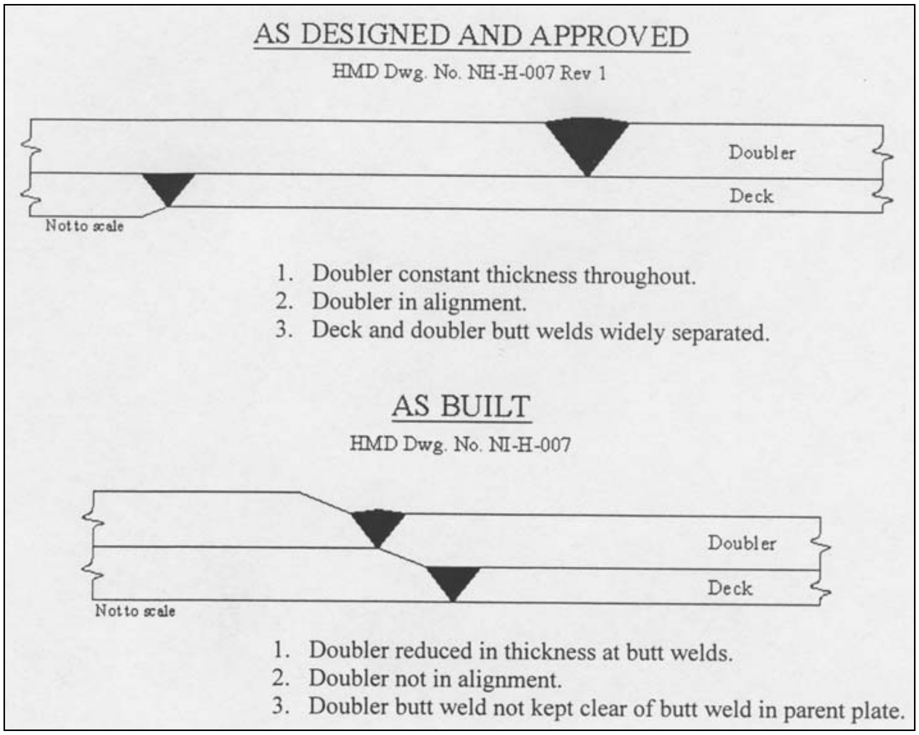

Figure 6. Deck and Doubler Alignment

<u>Quality Control</u>

In addition to items that were installed improperly, MSC CARLA's lengthening was plagued by poor welding quality. While the butt welds of the doubler straps were meant to be full penetration, they were not, and later inspection showed that many had significant slag inclusion. Following the casualty, forensic experts inspected the butt welds in way of the new midbody. Of 14 locations observed, six had been repaired previously, and nine had some fatigue cracking present.

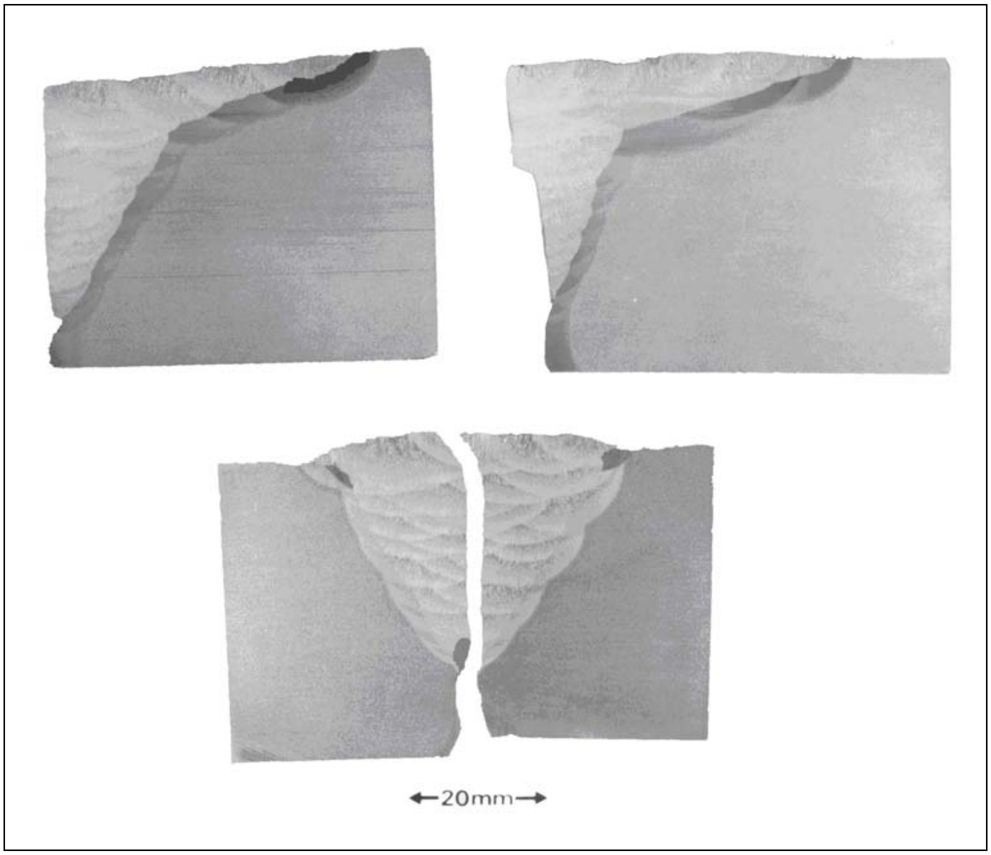

Figure 7. Doubler Strap Butt Welds with Insufficient Penetration

In any container ship, the longitudinal box girders are critical structure; they provide the bulk of the longitudinal strength at the deck level as well as torsional support to the vessel. Therefore, it is essential that their structure be installed properly and with great care. Following the MSC CARLA casualty, surveyors found serious fit-up and welding problems at the box girder corners both port and starboard. On the port side, it was evident that the deck plate and shear strake had not mated up correctly and an attempt had been made to fill this with weld material. On the starboard side a large cavity was present where the weld had not adequately penetrated to fill the beveling at the joint. It is at this location that the fracture is believed to have originated.

Figure 8. Excessive Weld Material, Port Side Joint

Figure 9. Weld Cavity, Starboard Side

End Result

During litigation in US District Court, Hyundai offered several alternative theories regarding the failure of MSC CARLA. In spite of physical evidence to the contrary, they produced finite element analysis that predicted failure at the bottom prior to the deck. In addition, Hyundai accused the captain of choosing an inappropriate route, suggested the hatch cover flaws forward led to the sinking of the bow, and that the vessel might have been overloaded. While the US District Court found Hyundai liable for the casualty, the decision was later overturned by the Court of Appeals on jurisdictional grounds, finding that Korean law should govern. The case was not pursued in Korea.

Acknowledgements

Dr. Charles Cushing, PE contributed extensively to this case study.

References:

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