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[News analysis] "Sewol science" and international maritime safety

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A Dutch Research Institute assessment on the lessons of the Sewol ferry disaster

Above: MV Sewol heeling to the port side on Apr. 16, 2014. (Provided by Special Investigation Commission on 4.16 Sewol Ferry Disaster). Bottom: MARIN's Model 9929 of MV Sewol (length, 573 cm, width, 87 cm). (Provided by MARIN)

In early March, researchers at MARIN, a maritime research institute located in Wageningen, the Netherlands, boarded an airplane bound for Athens, Greece. The COVID-19 epidemic was starting to spread in European countries, but the national borders were not closed yet. The MARIN researchers had been monitoring the situation with an option to cancel the trip, but finally decided to go as planned. On Mar. 4, they were supposed to attend an international conference on passenger ship safety held at the Greece Yacht Club, which was organized by the Royal Institution of Naval Architects (RINA), an international professional and academic society based in London. MARIN submitted two papers to this conference: "Heel Angles in Turn and Passenger Safety" and "Sewol Ferry Capsizing and Flooding."

Victor Ferrari, a senior project manager at MARIN, conducts tests with Model 9929 on Mar. 1, 2018. (Provided by MARIN)

MARIN's connection with the Sewol

In the morning session on Mar. 4, Victor Ferrari, a senior project manager at MARIN in charge of maneuvering studies and model tests, presented the paper "Heel Angles in Turn and Passenger Safety." He began the presentation with a photograph of MV Sewol (simply "the Sewol" henceforth) capsizing to the port side (the left side of the ship as you stand on the ship facing forward) on Apr. 16, 2014. Perhaps nothing can show the impact of heel angles (due to tilting of a ship to one side) on passenger safety better than this photograph of the Sewol. The photograph indicated that this scientific research paper with a rather abstract title focused on the sinking of the Sewol.

Ferrari's next slide showed photographs not of the Sewol itself, but of the Sewol model ship made by MARIN heeling to the port side in the huge basin. Ferrari added some simple words next to the photos in reference to the test conditions: "No Wind. No Waves. No Currents. No Damage. Only Turning." What attracted MARIN researchers' attention was the fact that, as observed in the model tests, a ship was cruising on a calm sea without an external shock but still heeled a lot during a turn, leading to a big catastrophe. In an email interview after the conference, Ferrari said, "the Sewol accident truly showed how terrible the consequences of heeling in turn could be." He then added, "We felt that such a tragedy should never happen again." Why did Ferrari and MARIN come to take the Sewol as a starting point for a study on international passenger ship safety?

MARIN's engagement with the Sewol goes back to early 2018. MARIN was one of the major contractors of the Sewol Investigation Commission (SIC) and throughout the first half of 2018 conducted model tests and simulations to find the cause of the Sewol's capsizing and sinking. At the time, the SIC chairman, commissioners, a sub-committee chair, and investigators visited MARIN to observe and participate in the tests. Some Sewol victims' family members joined the group as well to monitor the investigative process. Several media organizations sent reporters to cover the model tests and conduct interviews, indicating the public's high interest in the tests. In April and July 2018, MARIN submitted several reports to the SIC that were several hundred pages each.

2 kinds of model tests for analysis: fast turning and heeling , flooding and sinking

There were two kinds of model tests conducted by MARIN. The first is for the analysis of the fast turning and heeling and the second is for the analysis of its flooding and sinking within 100 minutes. For these tasks, MARIN constructed two model ships with the ratio of 1:25 and 1:30, respectively. These are called Model 9929 and Model 9930. (MARIN labels their model ships according to order of construction.) Model 9929 was equipped with devices to measure the overall behavior of the ship and to reenact the movement of cargo. For Model 9930, the ship's internal structure was precisely recreated for flooding sequence analysis.

The SIC accepted the results of model tests with Model 9930 without any disagreement. MARIN found out where the initial water intake occurred and how the flooding progressed. In particular, MARIN's simulation showed that, if its watertight doors and manholes had been closed properly, the Sewol would not have sunken as quickly as it did. This result was cited almost identically in both the SIC's reports "Internal Cause Theory" and "Open-Ended Proposal." Both reports state that "the Sewol was 'widely open' and vulnerable to flooding" and that the failure to maintain the watertight compartments caused the vessel to sink more quickly than could be usually expected.

In the tests with Model 9929 on turning and heeling, MARIN tested more than 340 scenarios that combined different conditions of speed, stability, cargo movement, rudder movements, and fin stabilizers. MARIN also conducted tests on the potential impact of "external force" on the ship's turning and heeling. According to MARIN's analysis, the combination of low stability and rudder movement caused the ship to heel at least 18 degrees to the port while turning to the starboard, at which point the cargo started to shift. When the ship heeled 33 degrees after the initial cargo movement, the second cargo shift occurred and the Sewol ended up heeling more than 45 degrees and did not recover its position. MARIN's conclusion was that we could explain the turning and heeling behavior of Sewol without introducing a hypothesis that there had been unknown 'external force' applied to the Sewol.

MARIN researchers visited the Sewol in Mokpo, South Jeolla Province, with SIC investigators on May 31, 2018. (Provided by Chihyung Jeon)

Disagreement within SIC on MARIN's analysis

There was a serious disagreement within the SIC on this analysis by MARIN. The "Internal Cause Theory" report of SIC accepted MARIN's results and interpretation, whereas the "Open-Ended Proposal" report of SIC did not accept MARIN's conclusion that Sewol's turning and heeling could be explained by a combination of stability, rudder angle, speed, etc. In particular, the "Open-Ended Proposal" report states that "there are many differences between MARIN and the SIC External Force TF" on how to interpret MARIN test results about the possibility of external force. Eventually, the biggest difference between the two SIC reports is found in Chapter 2, which deals with Sewol's turning and heeling, and it can be largely attributed to the different interpretations of MARIN test results.

MARIN heard the news that the SIC failed to reach an agreement internally and that SIC produced two versions of its final report at the time of the commission's closure in early August, 2018. The researchers were curious about public responses in Korea to the final SIC reports and subsequent discussions, as they hoped that their model tests contributed to the investigation of Sewol sinking. They could get some updates from the Korean media with the help of local contacts. The SIC, however, could not even send the final reports to MARIN, as the commission no longer existed by the time the final reports were published after the editing and design process.

The researchers in the Netherlands would not have been able to read it, but the different positions within SIC on MARIN's analysis and conclusion are visible in the ways in which the two reports refer to the Dutch institute. The "Internal Cause Theory" report states that the SIC selected MARIN as a partner in the Sewol investigation because it "highly appreciated MARIN's capability and experience in difficult and complex analysis," whereas the "Open-Ended Proposal" report states that it was because "MARIN had a good capability in model tests and was available, among the three organizations considered, for finishing the tests within the official investigation period." According to the former, MARIN has its own capacity for data analysis and making a conclusion. In the latter, MARIN is considered a contractor that conducts model tests as requested by its client.

This difference of opinions within SIC about MARIN's status, however, did not really matter to MARIN. Although the SIC, which had first commissioned the Dutch institute for model tests, ceased its work in August 2018, MARIN did not let go of Sewol. Instead, MARIN started to prepare a scientific publication based on its Sewol model tests since last summer. The product of this work is the other paper that the researchers presented at the RINA conference in March: "Sewol Ferry Capsizing and Flooding." Henk van den Boom, who had been in charge of the Sewol model test project in 2018, presented the paper himself. The co-authors include Ferrari, who conducted turning and heeling tests, Rinnert van Basten Batenburg, who conducted flooding and sinking tests, and Seo Seung-taek, who participated in the model tests as an investigator at the SIC.

MARIN's conclusion against external force hypothesis based on model tests

In the paper "Sewol Ferry Capsizing and Sinking," the MARIN researchers presented their analysis of the external force hypothesis more clearly: "Since no realistic combination of winch force, direction and duration attained the high rate of turn as derived by the External Force Task Force of SIC from the raw AIS heading, the hypothesis of an external force that caused such high values of rate of turn was rejected." This sentence appears in the conclusion section of the paper. It means that, although they applied forces to the model ship in several different conditions in order to replicate external forces, they could not attain a result in which the ship turned so quickly as to suspect external forces being the culprit behind its capsize. MARIN therefore concluded that it could "reject" the external force hypothesis based on its own analysis of the 2018 model tests.

In fact, a very similar sentence was in the conclusion of the "draft report" that MARIN submitted to the SIC at the end of July 2018, based on the additional model tests requested by the SIC. In the "final report" submitted a week later after receiving some feedback from the SIC, however, the explicit sentence about rejecting the external force hypothesis was not included. Therefore, the SIC's final report ("Internal Cause Theory") did not use a clear expression such as "the external force hypothesis was rejected." This time, the MARIN researchers brought back the sentence from the draft report of 2018 and re-confirmed their interpretation. In the email interview after the RINA conference, the MARIN researchers said that they were "fully confident" about their conclusion of rejecting the hypothesis of external force on Sewol. Their position has not changed from 2018.

MARIN's explanation of the Sewol sinking related to external force should have been discussed, verified, and concluded within the SIC in the summer of 2018. Without enough time to carefully review all investigation results, however, the SIC found itself in endless debates and was split into two groups supporting "Internal Cause Theory" and "Open-Ended Proposal," respectively. The SIC's final report, in its divided form, has not undergone an open process of review and verification by relevant academic societies. The English-language paper that MARIN researchers presented last month opens up a channel through which the international scientific community can have a detailed discussion on the official scientific investigation of the Sewol.

MARIN researcher Rinnert van Basten Batenburg talks about Model 9930 of MV Sewol to the visitors at the open house event held at the MARIN headquarters in Wageningen, the Netherlands, on Nov. 10, 2018. (Provided by MARIN)

MARIN researchers continued studies even after disbandment of SIC

In August 2018, when the SIC was disbanding itself without producing a unanimous conclusion, MARIN researchers were conducting another model test program -- with a model numbered 9974. The MARIN staff had worked on the model ship for several weeks, finished instrumentation on it, and then conducted model tests for three days. The outcome of this test with Model 9974 is the paper "Heel Angles in Turn and Passenger Safety" presented in Greece last month. This Model 9974 serves as a link between the Sewol accident and the general passenger ship safety.

Unlike Model 9929 and 9930 commissioned by the SIC, Model 9974 was built with MARIN's own research budget. It usually costs between 20,000 and 40,000 euros to build a model. Ferrari says that the institute uses some of its annual budget to conduct research for improving ship safety and efficiency. It reveals that MARIN made it a serious agenda to extend the case of Sewol to the problem of passenger ship safety regulation. What did MARIN want to find out with the new model ship?

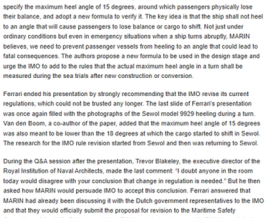
The International Maritime Organization (IMO) Intact Stability regulations for passenger ships adopted in 2008 provide a formula with which to calculate the heel angle from several characteristics of the ship. According to the rule, the heel angle in a turn calculated with this formula cannot exceed 10 degrees. In the stability range provided by the SIC and tested by MARIN, the Sewol did not meet that IMO formula, so it is not surprising that the Sewol heeled more than 10 degrees during the accident. Still, MARIN researchers took it seriously that, as observed in the model test, the ship heeled more than 18 degrees, enough to cause cargo movement, while cruising on a calm sea without any external force applied. Without a clear restriction on the maximum heel angle, it was shown once again, heeling during a turn could lead to fatal consequences. If we consider that many countries allow less strict lashing policies under good weather conditions, MARIN argues, we need to manage the maximum heel angle in a turn more rigorously to prevent dangerous cargo movement.

Current regulations ineffective at preventing accidents

In the paper presented last month, the MARIN researchers found out that the formula in the current Intact Stability code was not effective in limiting the actual maximum heel angle in a turn on the sea. Because the formula includes a ship's design parameters and its speed but does not take into account the hydrodynamic forces on a ship in a turn, satisfying the formula could not guarantee that the maximum heel angle would be within the safe range. From its long experience in model tests and trials of actual ships, MARIN knew a lot of cases in which the ships that satisfied the current formula heeled to dangerous angles in reality. MARIN's database from more than 200 model tests and trials with passenger ships had many cases of heeling more than 10, 15, or 20 degrees in a turn.

This problem has already been known to maritime professionals for a while. The same issue was officially presented and discussed at IMO between 2011 and 2015, but it did not lead to a revision of the code. It was concluded that more research was needed. A stronger set of data and rationale should be produced in order to persuade the IMO about the need for changing the regulation. The Sewol disaster added urgency to this task of strengthening the theoretical basis.

Model 9974 came into being for this purpose. The Sewol model 9929 could have provided data about heel angles in a turn, but a more representative model of passenger ships was needed for regulation revision. Model 9974 represents a more recent passenger ship design, 190m in length and 30m in width. With Model 9974, MARIN measured the heel angles in a turn by changing the conditions of stability, speed, and rudder angle, just as they had done in the Sewol tests. The model was designed to satisfy the current formula, but it was found occasionally to heel more than 20 degrees even under moderate navigation conditions. As in the case of Sewol, this could potentially lead to a big accident.



MARIN built Model 9974 to conduct research for the revision of IMO intact stability codes with its own research budget in 2018. (Provided by MARIN)

MARIN proposes revision of IMO regulations to specify maximum heel angle of 15 degrees

What needs to change, and how? In the paper, MARIN researchers propose that, because we cannot check the actual maximum heel angle with the current formula, the IMO should specify the maximum heel angle of 15 degrees, around which passengers physically lose their balance, and adopt a new formula to verify it. The key idea is that the ship shall not heel to an angle that will cause passengers to lose balance or cargo to shift. Not just under ordinary conditions but even in emergency situations when a ship turns abruptly, MARIN believes, we need to prevent passenger vessels from heeling to an angle that could lead to fatal consequences. The authors propose a new formula to be used in the design stage and urge the IMO to add to the rules that the actual maximum heel angle in a turn shall be measured during the sea trials after new construction or conversion.

Ferrari ended his presentation by strongly recommending that the IMO revise its current regulations, which could not be trusted any longer. The last slide of Ferrari's presentation was once again filled with the photographs of the Sewol model 9929 heeling during a turn. Van den Boom, a co-author of the paper, added that the maximum heel angle of 15 degrees was also meant to be lower than the 18 degrees at which the cargo started to shift in Sewol. The research for the IMO rule revision started from Sewol and then was returning to Sewol.

During the Q&A session after the presentation, Trevor Blakeley, the executive director of the Royal Institution of Naval Architects, made the last comment. "I doubt anyone in the room today would disagree with your conclusion that change in regulation is needed." But he then asked how MARIN would persuade IMO to accept this conclusion. Ferrari answered that MARIN had already been discussing it with the Dutch government representatives to the IMO and that they would officially submit the proposal for revision to the Maritime Safety Committee of the IMO. Blakeley said that RINA would clearly support it. RINA is participating in the IMO with an NGO status.

As Ferrari mentioned, MARIN has prepared a draft proposal to be submitted to the IMO officially. In a draft document titled "Proposal for a revision of a criterion of the 2008 Intact Stability Code for maximum angle of heel in turning," it is stated that this research was motivated by the sinking of the Sewol as well as the model tests for investigating its causes. This is where a catastrophe in the Southwestern coast of the Korean peninsula is connected to the general problem of passenger safety of the ships sailing on international seas.

It may take some months for the proposal to be discussed among European countries first and even years to go through all the review process at the IMO. Changing one international safety regulation is such an elaborate task. But it is certainly feasible. After the sinking of the Herald of Free Enterprise that killed 193 people in 1987, the IMO adopted a rule that requires the installation of indicators for the doors to the spaces prone to flooding (such as cargo compartments) on the navigation bridge. The sinking of MS Estonia in 1994 that killed 852 people also led to the revision of passenger ship stability rules.

In order for the proposal by MARIN and the Dutch government to be adopted, there needs to be support from respected institutions such as RINA but also many IMO member countries. Ferrari hoped that the Korean government, given its experience with the Sewol disaster, would support the proposal for revision. "Together we can help prevent such tragedies from happening again," said Ferrari. Through MARIN's work, the Sewol became a symbol of the catastrophe that every sea-going nation should work together to prevent. "If we do not strive to make safer ships now, then all the accident and subsequent events would have been in vain," Ferrari added. It's time for the Korean government to respond.

Henk van den Boom presenting the paper "Sewol Ferry Capsizing and Flooding" at the international conference on passenger ship safety held in Greece on Mar. 4. (Provided by Royal Institution of Naval Architects/Hellenic Institute of Marine Technology)

MARIN hopes finding cause of Sewol's sinking leads to new international regulations for safer passenger ships

Why is MARIN doing all this? Why are they still holding on to the Sewol, even after the project commissioned by the SIC, their client, officially ended in 2018? What does the Sewol mean to them?

Van den Boom, who has worked for 40 years at MARIN as a naval architect, spoke of the duty and responsibility of experts. "We at MARIN have done our best to contribute to the Sewol investigation in finding the causes of this disaster." MARIN believed that the scientific investigation of Sewol would be important not only for maritime safety but also for pursuing justice in the aftermath of the disaster in Korea. With its almost 90 years of history, MARIN mostly works with marine-related corporations and institutions that commission various projects, but it also emphasizes the "social responsibility" for making "a safer, more sustainable and better world." That is why MARIN started to work on additional model tests for stability code revision soon after it obtained results from Sewol model tests. "It is both a duty and an honor to contribute to this," said Van den Boom.

Van den Boom expressed similar thoughts two years ago. At the end of January 2018, when the Sewol model tests were underway, he said in an interview with the Hankyoreh that "a thorough investigation of the causes of the Sewol disaster is needed not just for Korea but also for international passenger ship safety." He also envisioned a possibility that "finding the cause of Sewol's sinking would lead to new international regulations for making safer passenger ships," just as earlier large-scale ship disasters had pushed the IMO to change its regulations. MARIN's recent work on scientific publications as well as the IMO proposal shows that his remarks two years ago were not a casual comment made in passing, but rather a promise. As experts, or as professionals, Van den Boom and his colleagues are still trying to keep the promise.

"Learning from our mistakes" or "taking lessons from disasters" are almost a cliché. Such learning, however, rarely happens. We are now witnessing how some European experts, who happened to be involved in the Sewol two years ago, are working to implement the lessons of the disaster. I am glad that they did not stop at Model 9929 and 9930 but proceeded to Model 9974, and I am curious about the outcome. Ferrari spoke about the significance of their work on the Sewol: "We cannot change the past but we can learn from it to improve the future."

During the Sewol model tests in 2018, the MARIN researchers, including Van den Boom and Ferrari, were wearing yellow ribbons, the symbol of Sewol. They still hope that their research and activity can offer some condolence to the Sewol families. In the email interview, they mentioned that Apr. 16 was soon approaching and sent a message of sympathy for the families. And some words of hope and promise as well: "We hope with this work to make a step towards safer ships, because no one should ever again go through the terrible ordeal that they suffered."

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