Damage stability regulations for ro-paxes

Concluding two previous articles published in the May and September 2017 editions of The Naval Architect [1, 2] and papers presented at RINA conferences over the past decade [3 to 9] Keith Hutchinson of Sabinah Group and Andrew Scott of the Maritime and Coastguard Agency discuss, following the introduction of SOLAS2020 at the beginning of this year, the current status and possible future developments of the damage stability regulations for ro-pax ships.

It is the 1990’s and 2000’s fundamental changes to the damage stability regulations for passenger ships contained within the Safety of Life at Sea (SOLAS) convention were considered by the International Maritime Organization (IMO). This involved the deterministic SOLAS90 regulations being replaced by regulations based on probabilistic methods. The aim was to produce revisions to the SOLAS Chapter II-1 damage stability regulations by continuing and harmonising the existing probabilistic regulations for dry cargo ships (SOLAS90 Chapter II-1, Part B-1, Regulations 25-1 to 25-10) and passenger ships (IMO Resolution A.265(VIII)) with newly drafted probabilistic damage stability regulations encompassing both dry cargo ships and passenger ships. This eventually culminated in the SOLAS2009 Amendments which entered into force on 1 January 2009 (IMO Resolution MSC.194(80)) together with the associated explanatory notes (IMO Resolution MSC.281(85)).

Even before the entry into force of SOLAS2009, doubts began to arise as to whether the harmonised probabilistic regulations would result in passenger ships, specifically large cruise and roll-on/roll-off passenger (ro-pax) ships, having an equivalent level of safety to the deterministic SOLAS90 regulations they were replacing. Hence, various amendments were found to be necessary to the regulations and the explanatory notes. Amendments to the regulations were finally approved under IMO Resolution MSC.421(98), adopted on 15 June 2017, and MSC.436(98), adopted on 24 May 2018, and entered into force on 1 January 2020. Amendments to the explanatory notes agreed since 2009 appear in IMO Resolution MSC.429(98), which was adopted on 9 June 2017, also entering into force on 1 January 2020. In totality, these are referred to as the SOLAS2020 Amendments and it is the damage stability aspects of these which are discussed in this article.

SOLAS2020 s factor
Work on the ro-pax ship damage stability agenda item spanned over five sessions of the IMO Sub-Committee on Stability and Load Lines and on Fishing Vessels (SLF), SLF.55 to 55 between 2008 and 2013, and eventually resulted in a significant change in one of the main probabilistic parameters – the s factor – which determines the likelihood that a given damage scenario is survivable in all sea states up to 4m significant wave height, HS. The s factor is derived by calculating residual stability characteristics such as righting lever, GZ, range and heel and post-processing these results through an equation which is supposed to predict the probability of survival after flooding of a given compartment or group of compartments. For example, an s factor of 1.0 for a given damage scenario implies that the ship will always survive that damage in any random sea state with a HS of up to 4m. An s factor of 0.5 implies that the ship will survive that damage in only 50% of randomised sea states and an s factor of zero (0.0) means that the ship will not survive that damage in any sea state.

As can be seen in Figure 1 the changes to the s factor in SOLAS2020 for ro-pax ships only, as approved at SLF and later adopted at IMO’s Maritime Safety Committee (MSC) (see below for details), makes it more difficult for such a ship to achieve an s factor of 1.0 when damaged in way of the garage space. For ro-ro passenger ships each damage case that involves a ro-ro space, THs = 16°, otherwise, and for ro-ro passenger passenger ships each damage case that involves a ro-ro space, THs = 25° for dry cargo ships; and THs = 30° for dry cargo ships.

These changes in SOLAS2020, which became known as the ‘20/20’ s factor, introduced for the first time a distinction between ro-pax ships and conventional passenger ships to reflect the vulnerability of the former to the effects of ingress of water onto the large open car deck.

SOLAS2020 R index
From the research projects underway during 2009 to 2012 doubts began to emerge as to whether the SOLAS2009 Required Subdivision Index, R, represented a sufficiently high level of safety. A value for R of 1.0 effectively means that any ships achieving this figure would survive all the damage cases in the IMO database up to a length of 60m in any randomised sea state up to 4m HS. A R index of 0.80 means survival of 80% of the damage cases, leaving 20% of the cases non-survivable. For ro-pax ships, ‘non-survivable’ could mean very rapid capsize in under 30 minutes with very little chance of orderly evacuation and hence a high casualty rate.

Passenger ships in contrast, not being vulnerable by virtue of a large open deck area to rapid capsize, and with a significant but unquantified volume of reserve buoyancy above the bulkhead deck, could survive longer and thus provide a better opportunity for passengers to evacuate in an orderly fashion. For this reason, the United Kingdom (UK) was always more worried about the safety standard of passenger ships, including ro-pax ships, by raising the R index to levels greater than those provided by SOLAS90.

For passenger ships, including ro-pax ships, the SOLAS2020 R index was derived from a regression formula based on subdivision length, Ls, the number of Persons On Board (POB), Nv, together with the lifeboat capacity (see below for the formula extracted from the Residual stability standards for passenger ships from SOLAS1960 to SOLAS2020)
so two knuckles were introduced into the plot internal subdivision for practical reasons and for smaller ships, it is difficult to increase equally important no matter how many were against aim for a more horizontal line in the plot of $R$ less with the number of persons carried, i.e. to determine independently under the SOLAS ship or the lifeboat capacity. The latter is now and not necessarily on the overall size of the SOLAS2009 as it was felt at IMO that it was determined. After much research and debate both at IMO and within the EU, a new formula for $R$ for passenger ships, which includes ro-pax ships, was eventually agreed at SDC 3 (IMO Sub-Committee on Ship Design and Construction – formerly SLF to 2013) early in 2016 and shortly afterwards approved for adoption into the SOLAS2020 amendments at MSC 96. The revision to $R$ in SOLAS2020 Chapter II-1, Part B-1, Regulation 7-2.3:

$$R = \frac{N}{1 + 2N_s}$$

where:

$N_s$ = Number of persons for whom lifeboats are provided,

$N = \text{Total number of Persons on Board (PoB)}$.

It will be noted that $R$ now only depends on $N$, not $L_s$ or the lifeboat capacity as in SOLAS2009 as it was felt at IMO that it was important to focus on the safety of passengers and not necessarily on the overall size of the ship or the lifeboat capacity. The latter is now determined independently under the SOLAS life-saving regulations in Chapter II-2. There was also the intent of making the $R$ index vary less with the number of persons carried, i.e. to aim for a more horizontal line in the plot of $R$ against $N$, as it was felt that peoples’ lives were equally important no matter how many were actually being transported onboard the ship. For smaller ships, it is difficult to increase internal subdivision for practical reasons and so two knuckles were introduced into the plot of $R$ versus $N$, as shown in Figure 2:

![Figure 2: Plots of $R$ against $L_s$ and $N$ to illustrate changes from SOLAS2009 to SOLAS2020](image)

The red line shows the passenger ship $R$ index as amended for SOLAS2020, the black lines being the SOLAS2009 passenger ship lines (depending on the number of persons carried in lifeboats) and the green line is the $R$ index for dry cargo ships, which remained unchanged for SOLAS2020 from SOLAS2009.

The exact quantity of flood water on the damaged vehicle deck. The exact quantity of flood water assumed to be taken onboard the car deck is dependent upon the residual freeboard in way of the damage opening and the sea-state (up to an assumed maximum of 4m HS with each sea area within North-West European waters being assigned a figure for HS. Compliance can be demonstrated either by calculation or by model testing. It is noteworthy that the Stockholm Agreement was never universally adopted by IMO, remaining a regional agreement to this day, and that few, if any, non-European IMO member states ever voluntarily adopted it. It was originally intended that these requirements would be revoked on 1 January 2009 but concerns over the safety levels provided by the SOLAS2009 Amendments led to a decision by the EU to retain the Stockholm Agreement to be used in conjunction with the SOLAS2009 Amendments. The current amendments to SOLAS2009 have still not completely allayed the safety concerns. At the time of writing the Stockholm Agreement has not been revoked for new ships constructed on or after 1 January 2020. A decision is to be taken by the EU based on the results of a three-year research project.

As the future of the Stockholm Agreement is concerned, one view is that the EU should retain it for a few years after 1 January 2020 and require that model tests be conducted on each new ro-pax ship to provide more data on the ability of the new ‘20-20’ $s$ factor to predict survivability, its predecessor was rather poor in that respect. If retained, the Stockholm Agreement will continue to have a major constraining influence on the subdivision of ro-pax ships, particularly those fitted with long lower holds (LLHs), since retention of protective B/S longitudinal bulkheads would be almost obligatory.

Only when all parties are convinced that the various formulations used in the probabilistic damage stability regulations are robust and reliably producing ‘safe’ ro-pax ships should we have the confidence to allow ship designers to utilise the full freedom provided by the probabilistic method to innovate new and more efficient internal subdivision arrangements.
as some relief to the owners and operators of ro-pax ships in terms of planning ahead and optimising new designs.

The UK’s Maritime and Coastguard Agency (MCA) is in the process of producing a document entitled ‘Instructions for Surveyors – Damage Stability Guidance Manual’ which will be accessible via the GOV.UK website using the reference number MSIS 42. It will be a ‘live’ document, regularly updated, containing the latest SOLAS Chapter II-1 amendments with explanatory notes and the UK’s own interpretation of regulations hitherto left to the ‘satisfaction of the Administration’.

Conclusions
The combination of the change in SOLAS2020 regarding the s factor for ro-pax ships together with the general increase in the R index for all passenger ships, including ro-paxes, will undoubtedly result in safer ships constructed on or after 1 January 2020 but will present a major challenge to designers to ensure their continued economic viability, especially for ships fitted with long lower holds. NA

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References