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Improvement of ship stability and safety in intact condition through operational measures: challenges and opportunities

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ABSTRACT

Attaining a sufficient level of safety from the point of view of stability is typically considered to be a matter of design. However, it is impossible to ensure safety only by design measures, and operational measures can then represent a complementary tool for efficiently and cost-effectively increasing the overall safety of the vessel. Time could therefore be coming for systematically considering operational measures as a recognised and regulated integral part of a holistic approach to ship safety from the point of view of stability. This paper therefore aims at capturing recent trends of research targeting operational safety measures, with specific attention to the intact ship condition. Open challenges and opportunities for research are identified, potential benefits and shortcomings of different options are discussed, and needs and possibilities for further developments in this area are explored. As an overall goal, this paper aims at providing food for thoughts as well as a ground for further proceeding towards the target of implementing a virtuous integrated approach to intact ship safety, from the point of view of stability, which gives due credit to effective and robust operational risk control options.

1. Introduction

Attaining a sufficient level of safety from the point of view of stability is typically considered to be a matter of design. It is indeed often assumed that the required level of safety is to be guaranteed by implementing proper passive measures at the design stage, in the form of design characteristics (hull shape, subdivision, systems redundancy, etc.) and in the form of limitations on the acceptable loading conditions.

The matter of safety-by-design, both in intact and damaged condition, has been, and of course still is on top of the agenda, especially regarding the rule-making process. However, it is impossible to ensure safety only by design measures, and design rules implicitly assume a certain level of knowledge, skills, experience and prudence of ship masters and crew. These human factors, which are commonly referred to as "good/prudent seamanship", hence represent a crucial aspect in determining the ship level of safety. The skills of existing officers are however challenged by rapid development of unconventional ship types and shipping solutions. In some dangerous, or potentially dangerous, operational situations, it can therefore be a great challenge for the ship officers to take the most appropriate decisions for reducing the risk level. Such situations can be effectively addressed by operational measures aimed at providing a decision support for the crew (Bačkalov et al., 2015; Bulian et al., 2015; Ovegård et al., 2012; Shigunov et al., 2010, 2013; Song and Kim, 2011). The implementation of operational risk control options can represent a valid tool for efficiently and cost-effectively increasing the overall level of safety of the vessel, both in intact and in damaged condition, also in those cases for which design changes would not be cost-effective. This is typically the case with issues associated with dangerous dynamic stability phenomena in intact condition.

In fact, looking at numerous accident reports it can be easily understood that several accidents could have been avoided, or at least mitigated, by implementing appropriate operational countermeasures. Depending on the case, such operational risk control

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options could be aimed at the prevention of the occurrence of the accident (measures aimed at the reduction of accident frequency/likelihood) or at the mitigation of its consequences.

Although operational measures become effective during the actual life at sea of the vessel, the combination of planning and implementation of such measures involves both the design and the operation phases of the vessel. It is therefore needed to properly "design operational safety measures", both for intact and for damaged condition. Indeed, operational measures are expected to be of different nature and to follow different approaches when considering an intact condition (a "normal state" of the vessel) and a damaged condition (an "abnormal state" of the vessel).

As a result, attaining a sufficient safety level through operational measures is linked with various aspects of the vessel (hull shape, ship handling, subdivision, cargo handling, systems design, etc.), with different phases of the vessel's life (from concept design to actual operation at sea), and with different stakeholders (ship officers, ship owner, cargo owner, shipyards and designers, class, administration).

It can therefore be understood that the concept of "ship stability and safety through operational measures" embraces a variety of conceptual, theoretical, technical, regulatory and educational challenges, calling for associated research and development efforts. The combination of passive design measures with active operational measures can therefore represent a virtuous holistic approach for increasing, in a cost-effective way, the overall level of safety of the vessel, and this concept is further elaborated in this paper with specific attention to the intact condition.

Present intact stability IMO/SOLAS regulations and class rules are mostly "design oriented" and based on an implicit "passive safety" concept, giving a limited attention to operational aspects, often in the form of qualitative, more than quantitative, indications. As a result, operational measures aimed at increasing the overall safety level of the vessel are put in place by ship owners and operators on the basis of a mostly voluntary, and not harmonised, approach.

This situation, where operational safety measures are neither facilitated nor sufficiently normed by the regulators, does not promote the implementation of approaches aimed at increasing safety through proper and cost-effective operational measures. The eventual result is a lack of promotion of holistic approaches to safety, with consequent missing of opportunities for a potential increase of the fleet safety level.

An example of what the shipping system is possibly missing in terms of potential increase of safety can be found by looking at the experience from a European PCTC operator (Huss, 2014; Ovegård et al., 2012; Söder et al., 2012, 2013). In such case, the occurrence of large amplitude motions, associated with phenomena driven by variations of restoring moment in waves, have been significantly decreased by implementing a holistic pro-active framework including a chain of activities: design optimisation to ascertain ships' hull forms which are sufficiently robust for their intended service (using extensive numerical simulations and model experiments); continuous recording of ship motions and wave measurements with associated analysis and follow up (particularly in case of occurrence of dangerous events); education of all officers (with particular reference to the dangerous phenomena the vessel can be prone to); and onboard installation of operational guidance systems. As can be noticed, such activities embrace all the phases of the life of the vessel, and are targeting the vessel design, the vessel operation, and the education of the crew. The implementation of such a framework was eventually successful, leading to a reduction of parametric rolling events to a very low rate.

There are therefore many opportunities for research and development associated with the idea of giving a more systematic and quantifiable importance to operational measures. At the same time, however, there are also numerous challenges. Originally prepared as a contribution in support of a workshop organised at the 12th International Conference on Stability of Ships and Ocean Vehicles (STAB2015), and herein extended and revised, this paper therefore aims at capturing recent trends of research targeting operational safety measures in intact condition. Furthermore, the paper discusses potential benefits and shortcomings of different possible options and explores needs and possibilities for further developments in this area. In this context, some ideas regarding opportunities and open challenges have been collected in the following, where the discussion is split in three sections, namely: design, regulatory and classification aspects; tools and methodologies; implementation in operation. However, a sharp separation proved to be very difficult since several of the given considerations are actually conceptually spanning more than one, and in some cases, all the three sections. As a result, some topics appear in more than one section taking, however, a different flavour depending on the perspective they are looked from.

2. Design, regulatory and classification aspects

Presently, ship stability in intact condition is normed by "design oriented" IMO/SOLAS regulations or class rules. The design approach is typically aimed at verifying specific loading conditions and at determining limitations in terms of acceptable KG values, to guarantee a "sufficient static roll restoring" according to specific requirements. Fulfilment of such requirements is implicitly assumed to provide a "sufficient level of safety".

Some general indications are given by regulations regarding the risk involved in having too large static restoring, since this can lead to excessive accelerations (Shigunov et al., 2011). However, such indications do not typically translate into quantitative limitations on GM. Some quantitative indications regarding too large metacentric heights can be applied in the preparation of the cargo securing manual, for those vessels for which this is relevant.

The main weakness of such approach is that the criteria used for the determination of acceptable/unacceptable loading conditions are mostly semi-empirical in nature, and do not provide explicit information regarding the specific possibly dangerous phenomena a vessel could be prone to in a specific loading condition. Furthermore, in some cases, existing regulations do not sufficiently or properly cover certain dangerous phenomena, which are typically associated with large amplitude ship motions under the action of wind and waves.

As a result of this situation, it might happen that a vessel may undergo crew injuries or cargo loss or damage in heavy seas despite fulfilling existing regulations. Conversely, it might happen that a vessel, marginally complying with existing regulations, still has a sufficient level of safety potentially allowing for a further increase of payload and, thus, profitability. In addition to this, the strongly semi-empirical and statistical nature of present regulations does not provide the master with any information regarding the expected behaviour of the vessel at sea. The lack of information, in turn, can lead the master to take wrong decisions in case of a dangerous situation (e.g. selecting unfavourable speed and/or heading in harsh environmental conditions). Also, the present regulatory framework is not designed for incorporating active operational measures as a means for providing the required level of safety in certain, potentially dangerous, conditions.

The mentioned limitations in the prevailing regulatory framework have recently been tackled, conceptually, in the development of the IMO Second Generation Intact Stability Criteria (SGISC) (Bačkalov et al., 2015; Peters et al., 2012). Indeed, in the framework of SGISC, specific criteria are developed for specific dangerous stability phenomena in waves. This allows identifying, at the