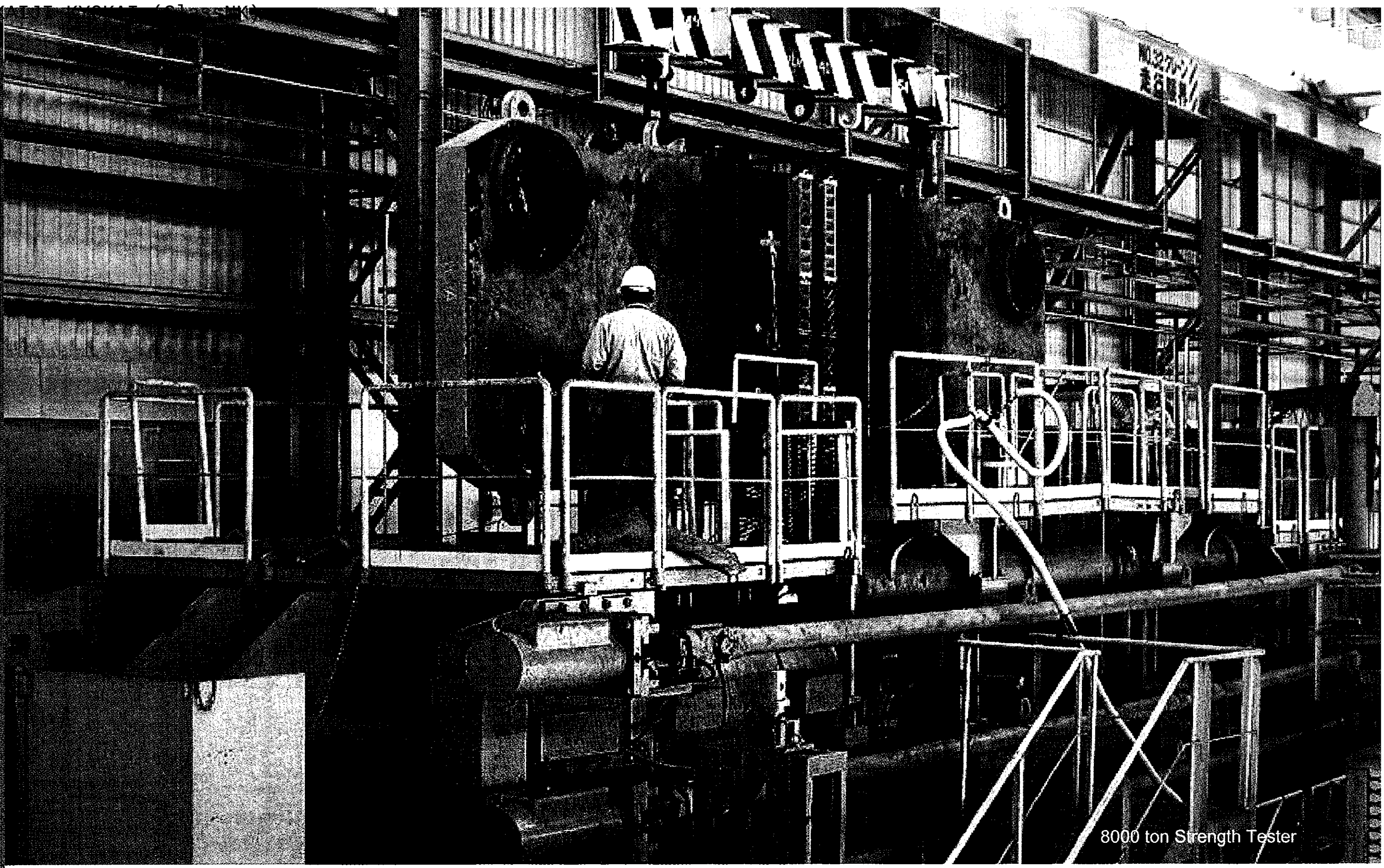


8000 ton Strength Tester

YP47

Ensuring the safety of ultra large containerships

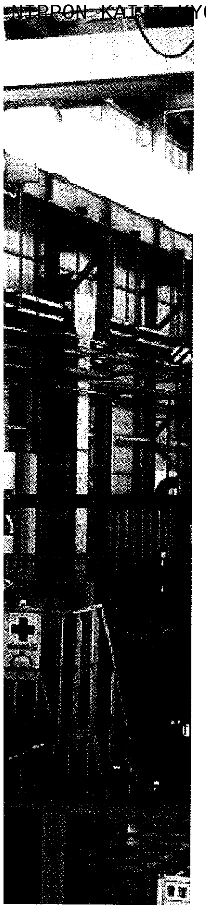
The development of YP47 high strength steel and methods for arresting brittle cracks

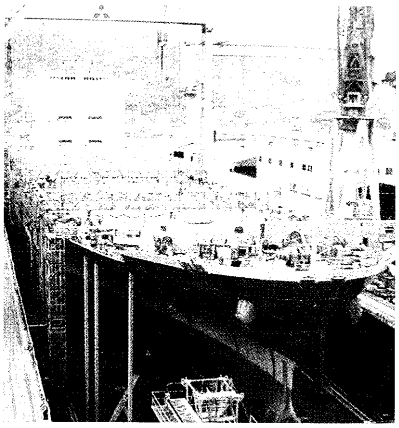
The ever-greater demands of international trade are driving a transition toward the use of ships of ever-greater size and efficiency. Nowhere is this more apparent than in the containership market, where ships of sizes once unimaginable are becoming commonplace. Less than two decades ago, the largest containership could only carry 5,000 TEU. Yet this year alone, orders have already been placed for ships of up to 14,000 TEU in size, and shipbuilders have unveiled designs for ships approaching 16,000 TEU and even for 18,000 TEU Malaccamax ultra-mega sized carriers.

The increasing size of containerships has led to the use of ever larger and thicker steel plates, especially in the construction of strength deck structures, such as hatch side coamings, strength deck, sheer strakes, and longitudinal bulkheads, in order to accommodate greater loads. These plates can exceed 70 mm in thickness, with some plates reaching thicknesses of up to 100 mm, sizes previously uncommon in shipbuilding. Such thick steel plates are used in the construction of containerships in order to satisfy the requirements for longitudinal hull girder strength, especially in light of the open deck design of these ships. The open deck design means that longitudinal strength must be ensured with limited structural members. The application of such extremely thick steel plates in hull structures, however, raises concerns about:

- the tendency towards a decline in toughness as plates become thicker;
- the adequacy of strength to resist brittle fracture in the base metal and welded joints, including preventing the occurrence of brittle fracture and arresting the propagation of brittle cracks;
- the assembly, fitting and welding work of the hull structures due to the resulting increase in weight to be handled; and
- the quality control (welding work, non-destructive inspection, etc.) of welded joints on extremely thick plates.

In order to address these concerns, ClassNK has cooperated with Nippon Steel and Mitsubishi Heavy Industries in the development and practical application of a new grade of higher tensile steel plate with a specified yield point of 47 kgf/mm2, known as YP47 steel plate, since 2001. This has led to the construction of the *MOL CREATION*, a 8,110 TEU





The *MOL CREATION*, the first ship in the world to use YP47 in its construction

containership built at the Mitsubishi Heavy Industries Nagasaki Shipyard & Machinery Works in 2007 to NK class as the first ship in the world to utilize the new YP47 high strength steel plating. Five sister ships using YP47 steel plate have already been delivered, and a number of other other containerships are scheduled be built in Japan and overseas using the new material. YP47 steel plate is tougher and stronger yet less thick than comparable types of steel used until now. Further, as YP47 incorporates brittle crack arrest as part of its design, the use of YP47 steel not only contributes to weight reduction and improved fuel efficiency but also helps to increase the reliability of the ship's hull.

Another result of this cooperation was the publication of *Guidelines on the Application of YP47 Steel Plates in the Strength Deck Construction of Ultra Large Container Ships* by ClassNK. The Guidelines set forth requirements for four major areas:

- the hull structure, including hull girder strength and higher tensile steel factors, fatigue strength, application of steel grades to hull structural members, and brittle crack arrest design;
- steel material requirements and approval of manufacturing processes, including the approval of steel materials;
- welding work, welding procedures including welding joint requirements, and welding materials; and
- inspections with particular focus on non-destructive inspections. →

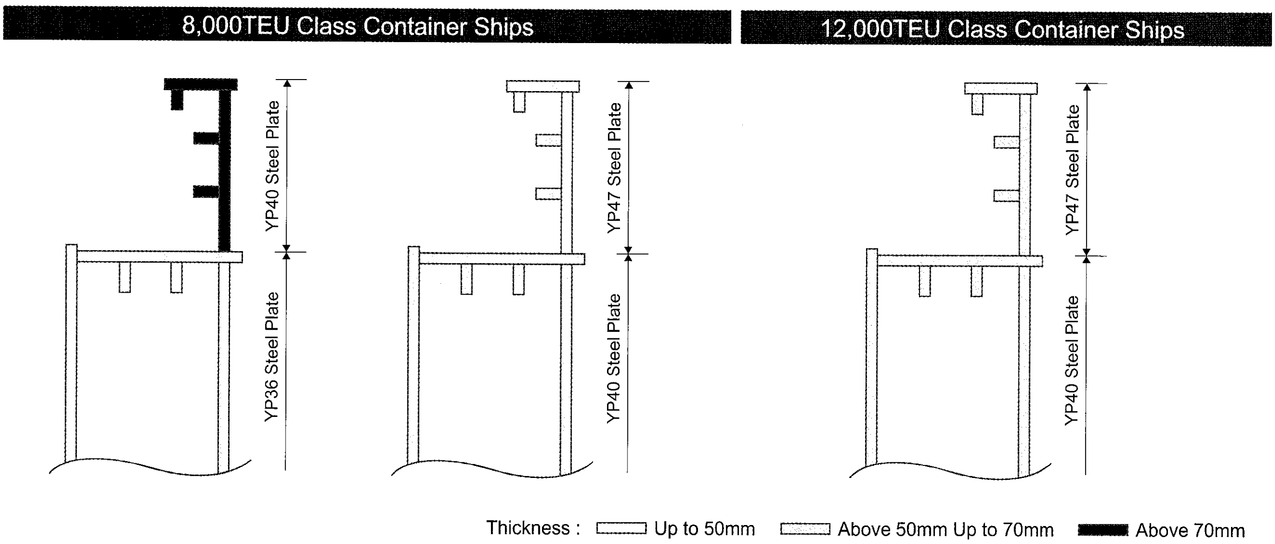


Fig. 1: Example of strength deck structures of ultra large containerships (application of YP47 steel plates).

➜ ClassNK has also been conducting practical research studies in cooperation with industry partners on the application of higher strength steel plates of heavy thickness in 10,000 TEU to 12,000 TEU class containerships. In these studies, particular attention has been paid to the brittle fracture toughness of the steel plates, brittle crack arrestability, and the quality of welded joints.

Preventing brittle fracture and ensuring brittle crack arrestability are of primary importance in ensuring the structural reliability of containerships. Classification society rules have prescribed stringent toughness requirements as a major aspect in the specifications of steel plate, material selection, toughness of welded joints, and the like, with a view to preventing the initiation of brittle fracture. Recent large-scale model tests have shown that the introduction of backup brittle crack arresting elements in strength deck construction is one of the most effective ways of preventing crack propagation. As a result, ClassNK has developed and included special requirements for steels with brittle crack arrest properties in its technical rules since 2006. These requirements have been verified by large-scale tests and have been applied in the use of high strength YP47 steel in the construction of the first ultra large container vessels in the world to use this material.

Of special concern is the fact that when brittle cracks occur in the welds of very thick steel plates, they propagate in ways that are contrary to conventional wisdom. Recent testing shows that brittle cracks in very thick steel plates propagate in straight lines, without swerving or deviation. Moreover, such cracks may not stop and may continue propagating even after penetrating the parent material. This suggests that if a brittle crack does in fact occur in a hull structure using very thick steel plates, there is a risk that such a crack could propagate at high speed and cause a major or catastrophic accident, including failure or collapse of the hull structure. Thus, the proper study of the brittle crack propagation and behavior in very thick steel plates and the establishment of suitable technical standards to prevent the occurrence of brittle fracture accidents should be considered a critical matter of concern.

Since February 2007, ClassNK has been conducting a research and development project aimed at developing technical requirements and design methodologies for arresting

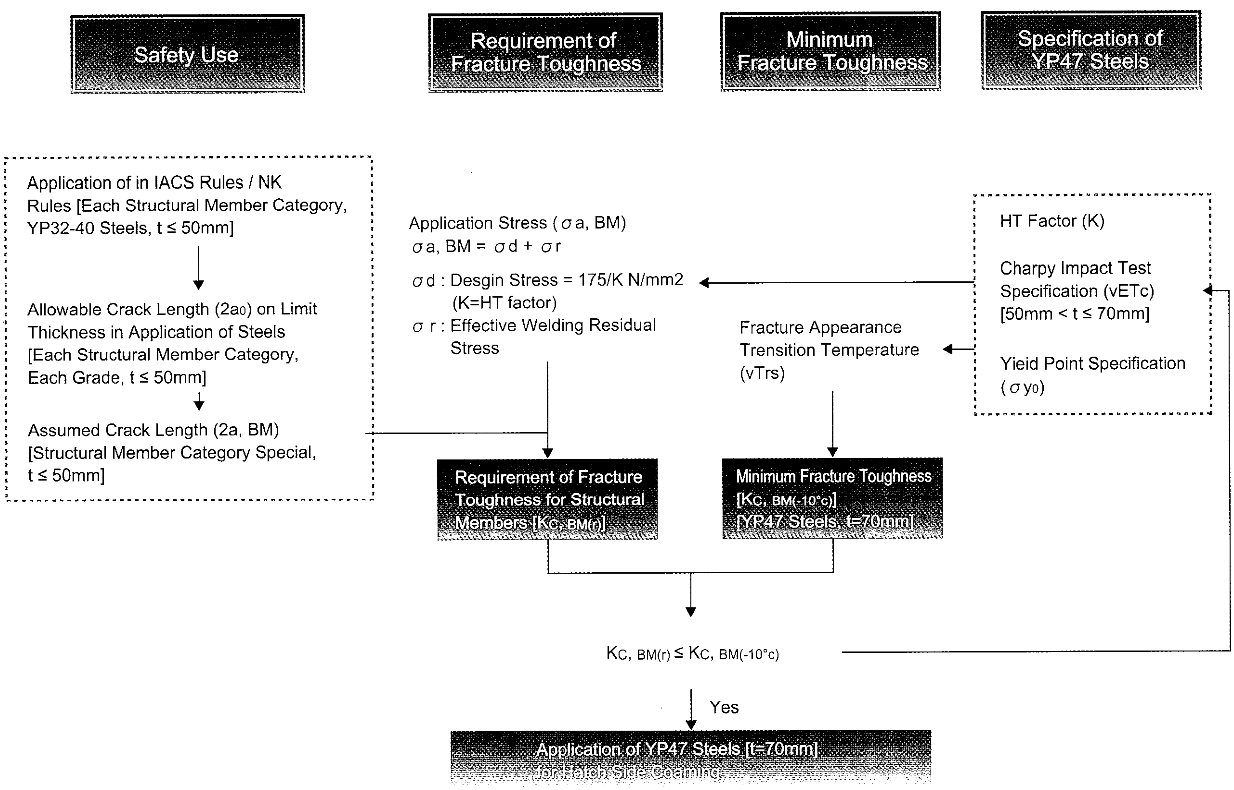
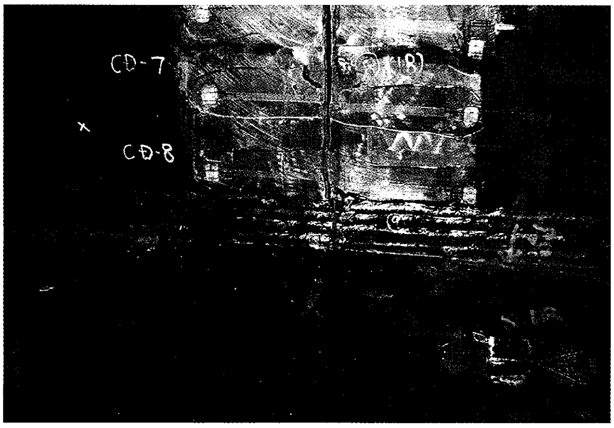


Fig. 2: Flow for evaluation of application of YP47 steel plates.


8th Meeting of the NK Brittle Crack Arrest Committee



Large scale crack arrest test (Crack arrest design)

brittle cracks in the thick steel plates used in ultra large containerships. This project is the latest in a series of studies started several years ago by the Society on the safe application of new thick and heavy, high-strength steel plates used in container ship construction. The current project has been conducted in cooperation with major shipbuilders, steel mills and other interested parties in Japan (six shipbuilders, four steel mills, two universities, and two institutes).

The project has been focused on the following main tasks:

- the conduct of large-scale model tests to establish technical standards relating to the brittle crack propagation behavior of very thick steel plates based on the latest cutting edge knowledge;
- the study of design methods that are effective in arresting the propagation of brittle cracks based on the knowledge obtained from the above tests; and
- the development of technical standards for designs incorporating suitable brittle crack arrest techniques, and at the same time study the establishment of related rule requirements.

Research is slated to conclude at the end of 2008 and it is expected that the outcome of this project will greatly contribute to enhancing the structural integrity of large and ultra large container ships classed with ClassNK. The outcome will be used to upgrade NK's own technical rules and provided to IACS in order to develop applicable IACS URs.

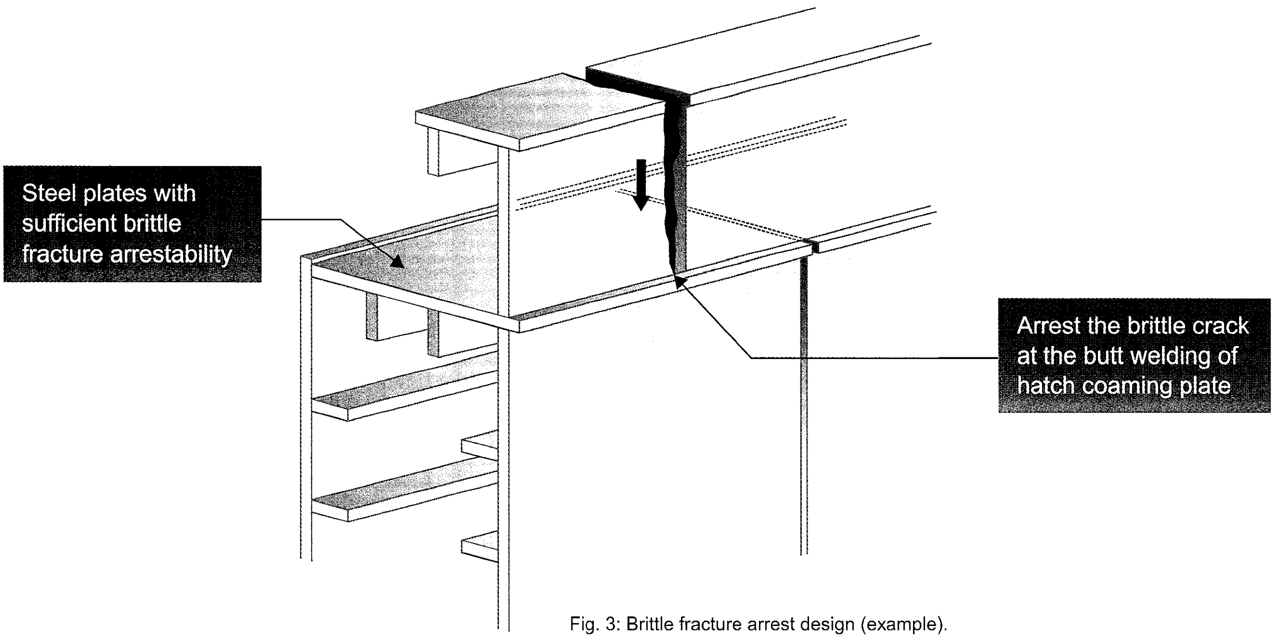


Fig. 3: Brittle fracture arrest design (example).