Journal of
Ship&Ocean
Technology
©DECEMBER 2001

SOTECH Vol. 5, No. 4, pp. 19~28, 2001

A Comparative Study of the Double Hull Structures for the Collision Energy Absorption Systems

J.W. Lee[1] and J.Y. Kim[1]

[1]The Inha University, 402-751 Inchon, Korea; E-mail: leejwook@inha.ac.kr

Abstract

A comparative study of the new flexible double hull structure is presented as a collision energy absorbing system, which is constructed with mixed stringers comprising slant and straight stringers for the double hull tanker. The dimension and disposition of this mixed stringers are selected to give the maximum absorbing energy. From the viewpoint of collision energy absorbing efficiency, this structural system is compared with three other types of the double hull constructions with trapezoidal stiffener, stringer type and standard type of VLCC, 310K DWT. Based on the constant hull weight, the proposed double hull structure with mixed stringers shows a improved crashworthiness as the results.

Keywords: VLCC, flexible double hull structure, mixed stringer, collision energy, crashworthiness

1 Introduction

Recently, many works have been devoted to the improvements of tanker structures and several proposals are presented as the efficient collision resistance structures (Lee et al 1999, Kitamura 1996, Ludophy and Boon 2000, Sikora and Michaelson 1995). The objective of the presentation is to develop the flexible structural system of energy absorbing type through structural large deformation in collision. The collision resistance of a ship hull comes from double hull structure system itself as a whole flexible structure and its structural members that deform elastically and plastically in crushing and tearing etc.. To demonstrate the effectiveness of the proposed side double hull structures with mixed stringers comprising slant and straight stringers, a comparative study on the collision resistance is carried out with standard double hull structure of 310K DWT class VLCC and other two types of double hull structures; the hat type and the stringer type. Before the comparison, a systematic analysis of the proposed structure for the dimension and disposition of the members is also performed. Numerical analysis of ship collision and crushing damage is applied to the comparative study and the characteristic behavior of the members in energy absorbing process is analyzed for the evaluation of double hull tankers.

2 New oil tanker with flexible double hull structure

The midship tank structure of standard 310K DWT VLCC is shown in Figure 1, which gives the reference collision resistance against side collision. The main characteristics of standard VLCC

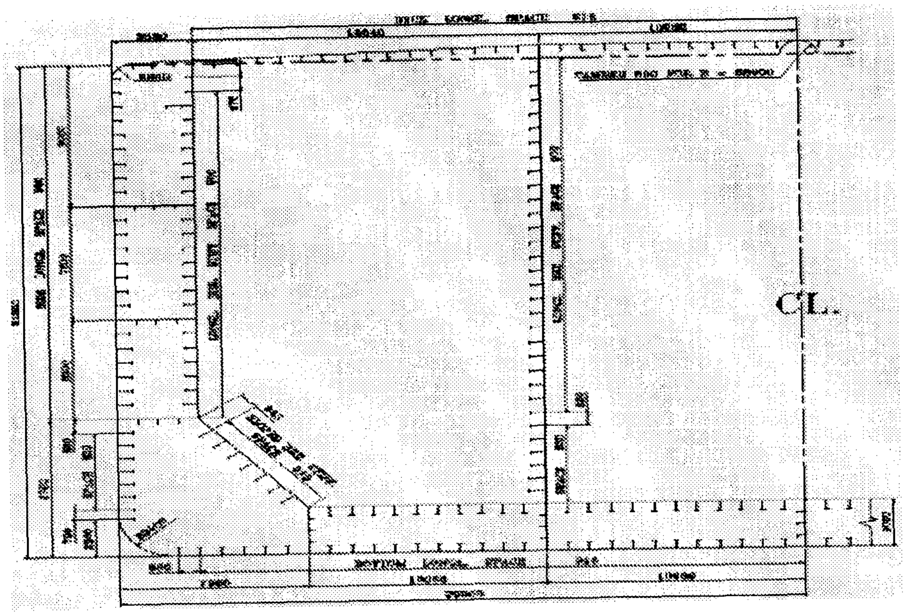
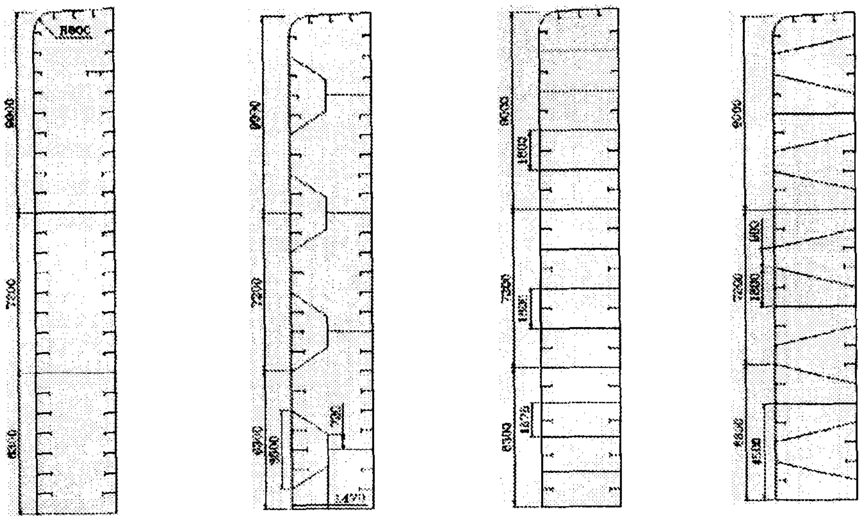


Figure 1: Midship section of standard VLCC

Table 1: Characteristics of standard and new VLCC

Width of Double Side	3380mm
Depth of Double Bottom	3000mm
Transverse Spacing	5080mm
Floor Spacing	5080mm
Typical Longl. Stiff. Spacing	900mm
Material of Deck Structure	YP320 HT Steel
Material of Double Side Structure	Mild Steel
Material of Inner Bottom Structure	Mild Steel
Material of Bottom Structure	YP320 HT Steel

are listed in Table 1. The hat type is composed of stiffeners with trapezoidal shape and stringers, which are arranged alternatively with the same spacing in vertical direction and the dimension of longitudinals with side shell and side longitudinal BHD have the same values with standard VLCC's(Ludophy and Boon 2000) as shown in Figure 2(b). The stringer type is arranged with straight stringers with stiffeners instead of longitudinals on side shell and side longitudinal BHD in standard VLCC. This stringers are arranged alternatively with the same spacing in vertical direction as shown in Figure 2(c). The disposed locations of stringers have the same locations of the longitudinals of standard VLCC as proposed by Sikora(1995). The mixed stringer type as proposed by authors in Figure 2(d) is composed of slant and straight stringers. The disposed locations of stringers have the same locations of the longitudinals of standard VLCC and it is arranged alternatively with the same spacing in vertical direction. As the proposed mixed stringer type of double hull structure was designed to have the same value of hull weight with the hat type and stringer type, the material cost would be the same order. However, the proposed mixed



(a) Standard VLCC (b) Hat Type (c) Stringer Type (d) Mixed Stringer Type

Figure 2: The typical sections of the standard and other double hull structures for comparison

Table 2: Dimensions of shell stiffeners for double hulls (Unit:mm)

Typical model	Hat Type	Stringer Type	Mixed Stringer Type
Scantling of stiffener	1440×3600×1470×6	-	-
Scantling of longl.	600×11.5 / 150×22	450×11.5 / 150×18	450×11.5 / 150×18
Thick. of stringer	6	8	7.5

stringer type is slightly heavier than the stringer type due to the length of slant stringers. Further study on the productivity is needed for the practical application of the structures.

3 Evaluation of collision resistance

3.1 Collision scenario

The principal dimensions of two ships which are participated in collision scenario, are listed in Table 3. Striking ship collides the center of struck ship's normally. Struck ship's displacement is 310K DWT and striking ship's one is 150K DWT Tanker in ballast condition, as was adopted in (Kitamura 1996). Observing the objective of this study; the development of efficient hull structure in energy absorption, we adopt the orthogonal collision case, as collision scenario. In this case hydrodynamic force is neglected, due to the simplification of structural analysis of developed struck oil-tanker. In the analysis, struck ship is modeled by one tank length and only double hull above hopper tanker. The total number of the elements of the simulation model is approx. 15,000 and the boundary condition is fixed at each side of the double hull structure. In the striking ship, bulbous bow assumes rigid, rid of all inner elements and the shape of the colliding bow has the

Table 3: Principal dimensions of two ships in collision scenario

Principal dimensions		Struck ship	Striking ship
Length	[m]	318	264
Breadth	[m]	58	47.8
Depth	[m]	31.25	22.8
Draft	[m]	21.4	14.6
Displacement	[ton]	310,000	150,000

spherical form with 12m diameter as shown in Figure 3. Collision speed is set constant value of 10m/s. For the fracture criterion, the following parameters are applied; 2.4E8 N/m2 for the yield stress of the material, maximum value of plastic strain, 0.2, for the Cowper-Symonds P and D factors, 40.4 and 5 respectively.

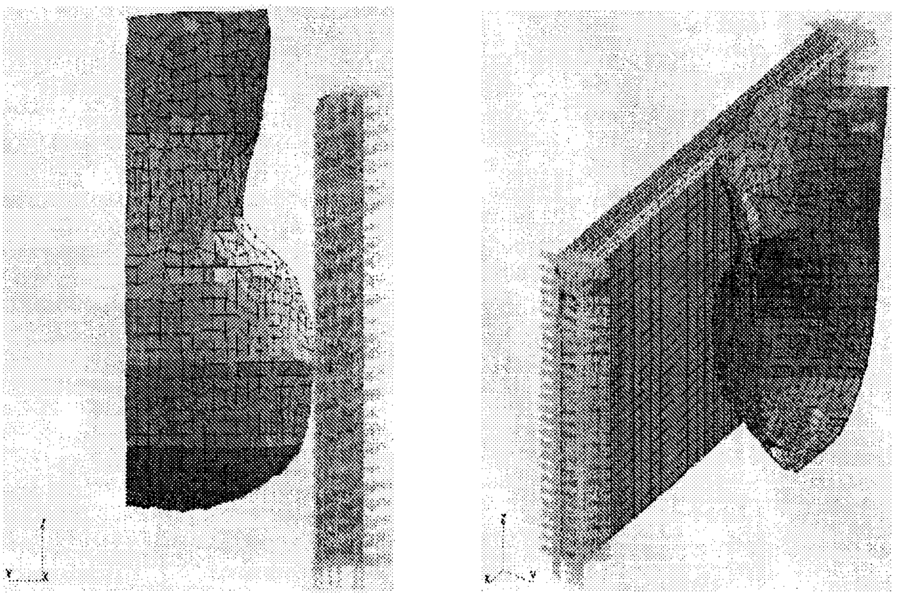


Figure 3: Side view of collision simulation model of double hull and bow structures

For the purpose of comparison of four different types of double hull structures, only the sectioned part of one hold side structure is modeled for the analysis of collision scenario in this study.

3.2 Contact force

The numerical analysis of the proposed side structure models in collision scenario is carried out by using the software MSC/DYTRAN, as an explicit solution method. The side collision damages of standard VLCC and the proposed double hulls at the rupture initiation of side longitudinal BHD are shown in Figure 4 to 7. The contact forces of standard VLCC, at initial stage, relatively higher than other proposed types, but it drops dramatically at the penetration depth 2m, due to the loss of side structure's rigidity. Whereas, the contact forces of stringer type is almost increased linearly without the severe change of forces as the bow penetration depth increases. It is the reason that the

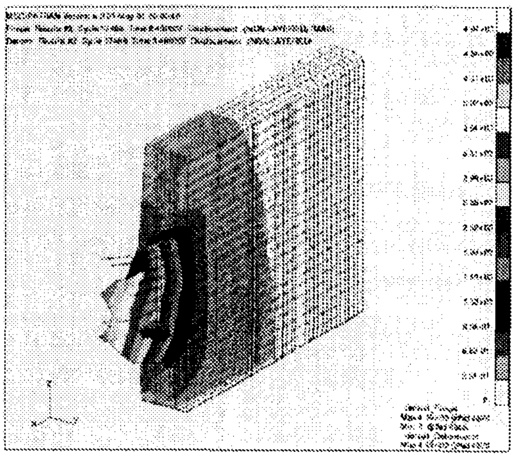


Figure 4: Side view of damaged double hull at the rupture initiation of Standard VLCC

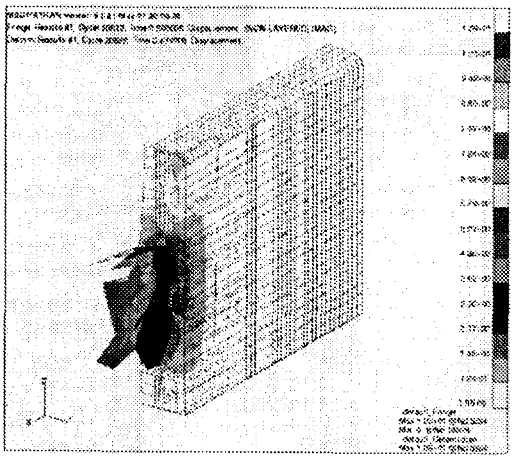


Figure 5: Side view of damaged double hull at the rupture initiation of Hat Type

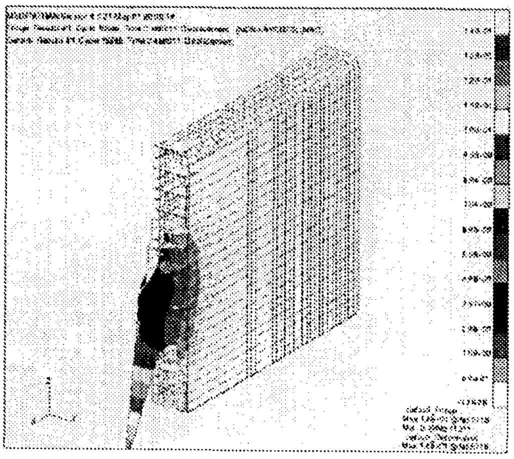


Figure 6: Side view of damaged double hull at the rupture initiation of Stringer Type

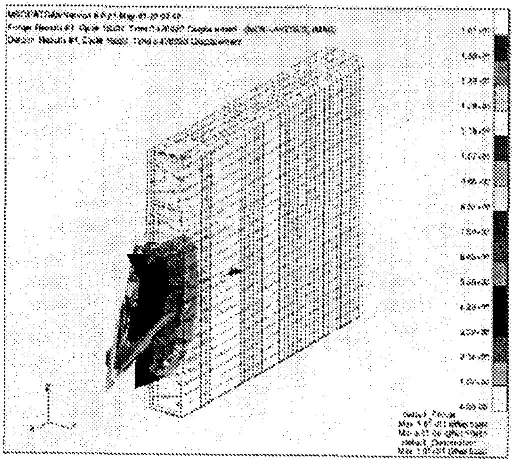


Figure 7: Side view of damaged double hull at the rupture initiation of Mixed Stringer Type

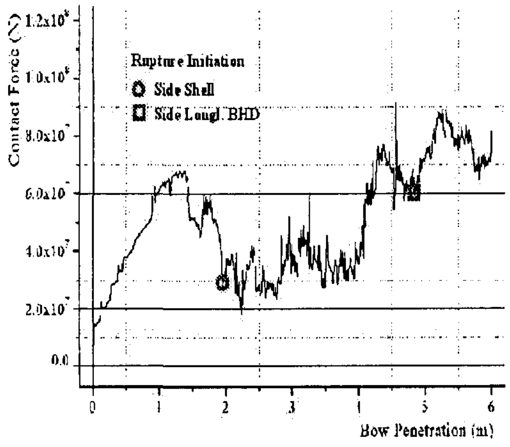


Figure 8: Contact forces of Standard VLCC

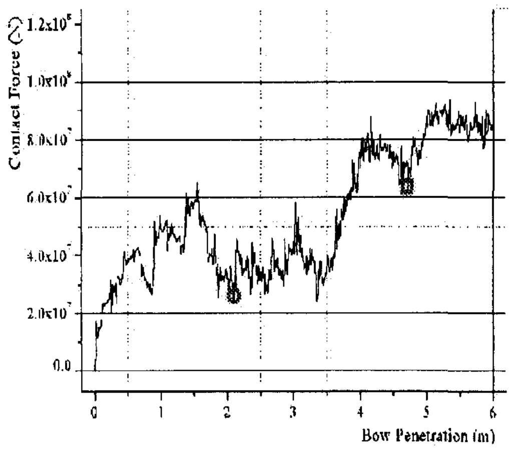


Figure 9: Contact forces of Hat Type

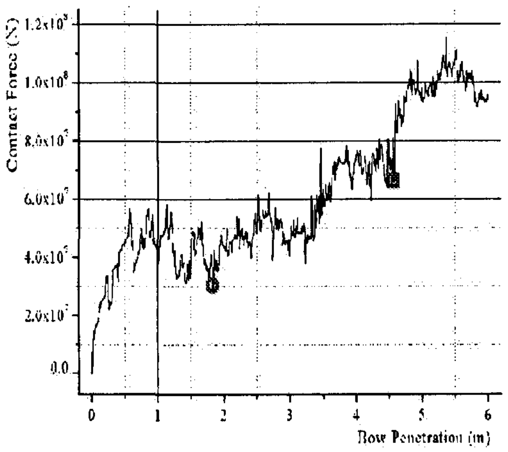


Figure 10: Contact forces of Stringer Type

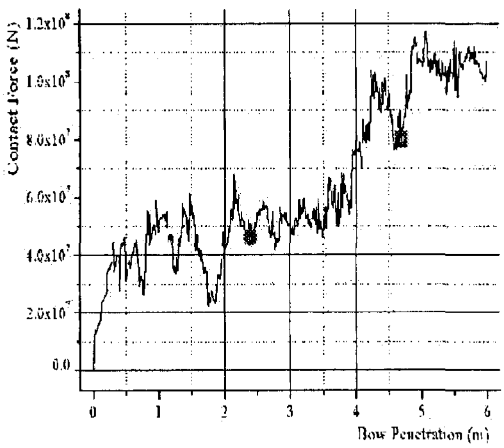


Figure 11: Contact forces of Mixed Stringer Type

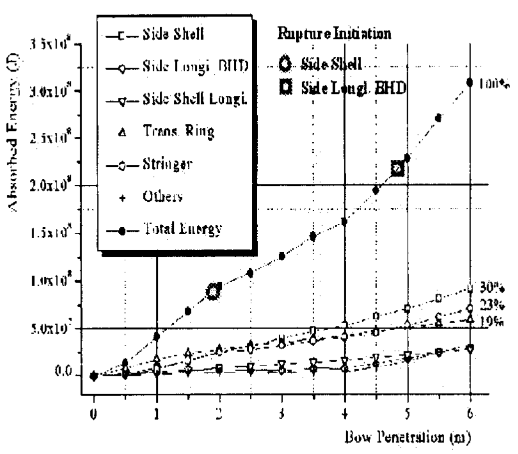


Figure 12: Energy absorption of structural members of Standard VLCC

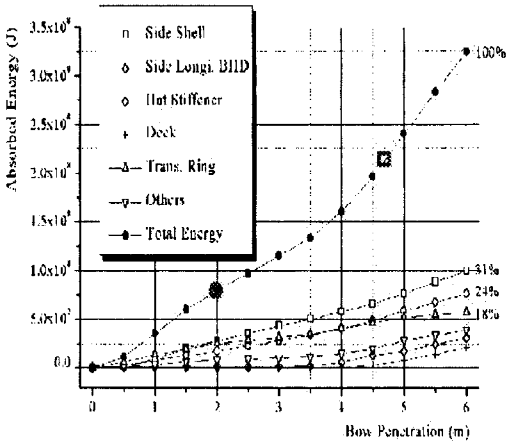


Figure 13: Energy absorption of structural members of Hat Type

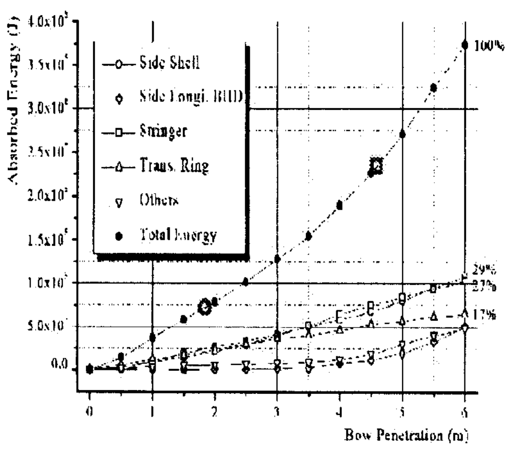


Figure 14: Energy absorption of structural members of Stringer Type

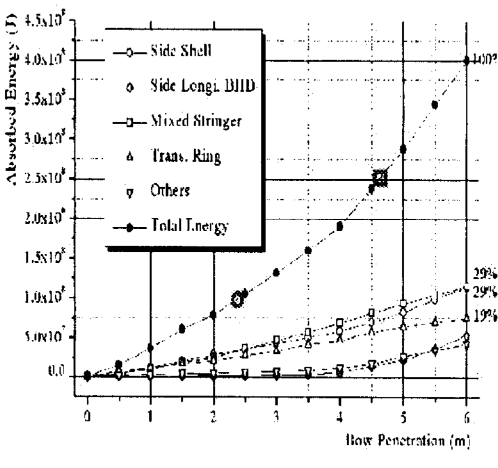


Figure 15: Energy absorption of structural members of Mixed Stringer Type

Table 4: Energy absorbing index of double hulls

Type	Standard VLCC	Hat Type	Stringer Type	Mixed Stringer Type
Energy Index	100	103	110	119

stringers disposed between side shell and side longitudinal BHD behave the plastic deformation with plate crushing behavior. On the other hand, the contact forces of the proposed double hull structure of mixed stringer type, at the initial stage, have the similar tendency of the hat type's. However the contact forces increase more than those of the stringer type's along the increased penetration depth until 6m. This behavior is resulted from the effective crushing performances of straight stringers through the plastic deformation and membrane effect of slant stringers. As the bow penetration depth increases, the contact forces of mixed stringer type increases due to the maintaining of rigidity of side structure as a whole.

3.3 The structural absorbing energy

The energy absorption of structural members of double hull structure is shown in Figure 12 for standard VLCC, in Figure 13 for the hat type, in Figure 14 for the stringer type and in Figure 15 for the proposed double hull with mixed stringers. In the cases of the standard VLCC and the hat type, the collision energies are absorbed in large quantity by side shell, whereas the stringer type and the mixed stringer type by stringers comparatively. The total absorbed energy of the double hull structure with mixed stringers shows the excellent behavior in the energy absorption among the four double hull structures. It is resulted from, as the bow penetration depth increases, the relative increase of energy absorption capacity of the flexible collapse behavior of the double hull members with side shell, slant stringers and straight stringers together. For the comparison of standard VLCC and the other three proposed oil-tankers, the relationship between the total absorbed energy and bow penetration depth is shown in Figure 16. At the first stage of the penetration depth 2m, the standard type presents the maximum value of absorbed energy due to the effective behavior of flexible stiffened side shell of the double hull structure. However, the absorbing energy of the proposed double hull with mixed stringers shows the highest value, as the bow penetration depth increases. Namely, the stringer type shows the maximum value of absorbed energy after the penetration depth of 4m owing to the increased membrane effects of side shell initiated from the force components of slant stringers. Therefore, it is understood that the proposed double hull structure with mixed stringers shows the most effective behavior in the sense of collision energy absorption among the other type of double hull structures in the major collision. The energy index of standard VLCC and the proposed double hulls is summarized on Table 4. The energy index is calculated with the percentage ratio of total absorbed energy until the rupture initiation of side longitudinal BHD and the total hull weight of one side double hull structure. Through the longitudinal strength calculation by the KR-TRAS program, the service strength of the four alternatives is verified to be similar. However the fatigue strength should be investigated further.

4 Conclusions

To develop the structural concept of double hull tanker as an energy absorbing system, a new flexible double hull structure with mixed stringers comprising slant and straight stringers is proposed

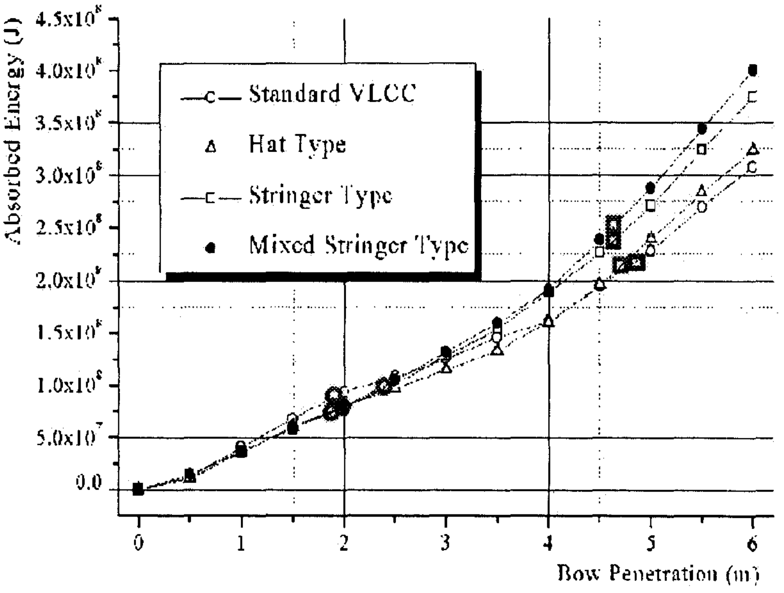


Figure 16: Comparison of absorbed energy for double hulls

and analyzed. And a comparative study on the collision resistance of this proposed double hull structure is carried out with the standard VLCC, the hat type and the stringer type structure. At the initial stage until the penetration depth 2m, the standard double hull shows a little better behavior than the other type of double hulls. However, the absorbing energy of the proposed double hull with mixed stringers shows the highest value, as the bow penetration depth increases. Therefore, it is understood that the proposed double hull structure with mixed stringers is most effective in the major collision. The proposed flexible double hull structure with mixed stringers can be recommended as a structural design of double hull tanker. For the detail design of structural connections, the fatigue assessment as well as economic evaluation should be carried out for further study.

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