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Ultimate strength of Y and T stiffeners subjected to lateral loads with three different levels of initial imperfection

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ABSTRACT

This paper aims to compare between ultimate strength of T and Y stiffeners when subjected to lateral load. Two groups of Y and T stiffeners are studied. In the first group, T stiffeners with standard dimensions are compared with Y stiffeners having the same section modulus, attached plate and weight. The plates of both types of stiffeners are subjected to uniform pressure. In the second group, both T and Y stiffeners share the same section modulus with different attached plate and weight, and a pressure load is applied to a small central area of the plate. The results are shown in 2 sets of curves. In the first set, perfect T stiffeners are compared with perfect Y stiffeners. In the second set, imperfect T stiffeners are compared with imperfect Y stiffeners. Also, perfect and imperfect T stiffeners are compared as well as perfect Y and imperfect Y stiffeners. Five perfect models of T and Y stiffeners having different dimensions with three levels of initial imperfections are studied in the two groups. Nine imperfect models branch from each of the five perfect models for both groups; 200 models are obtained and results from the FE analysis are shown in the form of load–displacement curves.

1. Introduction

Because of the overall effort to promote maritime safety and environmental protection, naval architects aim to design ship structures which are strong enough and capable of resisting the expected loads. This makes it possible to prevent failure which may cause pollution, total loss of ship and/or lives on board. Structural failure refers to loss of the load-carrying capacity of a component or member within a structure or of the structure itself. Structural failure is initiated when the material is stressed to its strength limit, thus causing fracture or excessive deformations. In a well-designed system, a localized failure should not cause immediate or even progressive collapse of the entire structure. Ultimate failure strength is one of the limit states that must be accounted for in structural engineering and structural design. Since stiffened plates are fundamental building blocks in ships; many researchers have contributed to ship plating using conventional stiffeners to support the plate. Recent international regulatory actions have resulted in significant changes to oil tanker designs and have intensified attention to predicting tanker environmental performance. Lateral loads acting on the shell plates whether in the bottom or in the side affect the ultimate strength of the hull. The description of the behavior of stiffened plates under predominantly lateral loads is relatively complicated due to the large number of possible combinations of plate and stiffener geometries, boundary conditions and loading. It is possible to carry out accurate predictions of ultimate strength for any type of stiffened plate configuration using the finite element method. This paper is mainly concerned with lateral loads on Y and T stiffened panels. Simulation has been carried out by Matlab program to produce different groups of Y-stiffened panels to replace real T stiffeners by relating the dimensions of the Y stiffeners to the T stiffeners under several constraints.

This paper involves a comparative study including finite element calculations, focusing on the prediction of the ultimate strength of Y and T stiffeners under lateral load.

It does not take into consideration the residual stresses. Residual stresses in a structural material are those stresses which exist in the object without the application of any service or other external loads. Manufacturing processes are the most common causes of residual stress. Virtually all manufacturing and fabricating processes such as casting, welding, machining, molding, heat treatment, plastic deformation during bending, rolling or forging introduce residual stresses into the manufactured object. Residual stress could be caused by local yielding of the material, because of a sharp notch or from certain surface treatments like shot peening or surface hardening.

2. Review of previous work

Many researchers have studied conventional and nonconventional stiffened panels under certain loads. This work focuses on

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stiffened panels under lateral loads. General problems of lateral loads in panels have been discussed by Belenkiy and Raskin (2001) who used the nonlinear FE analysis to determine the ultimate loads of stiffened ship structures subjected to lateral loads. Teixeira and Soares (2001) have presented the results of a parametric study to quantify the effect of lateral pressure on the collapse of square and rectangular steel plates under a predominantly compressive load. Virág (2006) in his overview of loaded stiffened plates has investigated various plate types, loadings, and stiffener shapes. Fujikubo et al. (2005) have conducted and presented a set of design formulae to estimate the ultimate strength of a continuous stiffened panel subjected to combined transverse thrust and lateral pressure. Khedmati and Nazari (2012) presented the results of a numerical investigation into the structural behavior of preloaded tubular members under lateral impact loads by means of finite element method. The lateral load represents a statically modeled impact from collision between tubular member and a solid rectangular indenter. Khedmati et al. (2010) developed empirical expressions for predicting ultimate compressive strength of welded stiffened aluminum plates used in marine applications under combined in-plane axial compression and different levels of lateral pressure.

The Y-stiffener concept was introduced by Ludolphy (2001) who introduced the Y stiffener and proved that it has a significantly higher resistance against collisions and grounding than the traditional stiffeners. The energy absorption by the Y stiffener has been studied by Naar et al. (2002). Tests of Y-stiffeners were carried out by Badran et al. (2007) who studied the stability of Y stiffeners analytically and thus obtained approximate expressions for calculation of the elastic buckling coefficients of the T part of the Y stiffener. Also, the critical buckling load of Y stiffeners was calculated for two studied groups with different boundary conditions and compared with T stiffeners as has been presented by Badran et al. (2008). Multi-objective optimization with real-coded genetic algorithms for designing optimum Y stiffeners under the action of uniaxial compressive loads have been presented by Badran et al. (2009).

The stability of T-stiffeners was studied by Byklum et al. (2004) who derived a computational model for global buckling and postbuckling analysis of stiffened panels. The loads considered were biaxial in-plane compression or tension, shear, and lateral pressure. Bedair (1997) has investigated the elastic behavior of stiffened plates under non-uniform edge compression. Graciano and Lagerqvist (2003) have described a methodology for the determination of buckling coefficients for longitudinally stiffened plate girders subjected to partial edge loading or concentrated loads. Saddek (2006) developed a finite element model using ANSYS to investigate the effect of large displacements on the behavior due to buckling and four girders were tested subjected to two concentrated loads. Featherston (2001) used finite element analysis to present the effects of imperfection shape and amplitude on the buckling and postbuckling behavior of one specific case. Some researchers considered only axial loads such as Aalberg et al. (2001), who carried out axial compression tests on longitudinally stiffened aluminum panels. Paik and Kim (2002) conducted and studied the accuracy of simplified formulations for prediction of the ultimate strength of longitudinally stiffened panels under uniaxial compression. Also, Paik (2007) has developed design-oriented ultimate strength expressions for stiffened panels subject to combined axial load, in-plane bending and lateral pressure. Sheikh et al. (2003) have presented a part of a series of investigations of the behavior of steel plates stiffened with tee-shaped stiffeners and loaded with axial compressive forces with or without bending moments. Xie and Chapman (2003) have examined the effects causing axial forces in stiffeners.

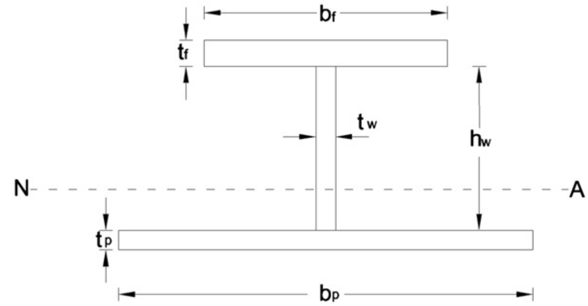

Fig. 1. Geometry of T stiffeners.

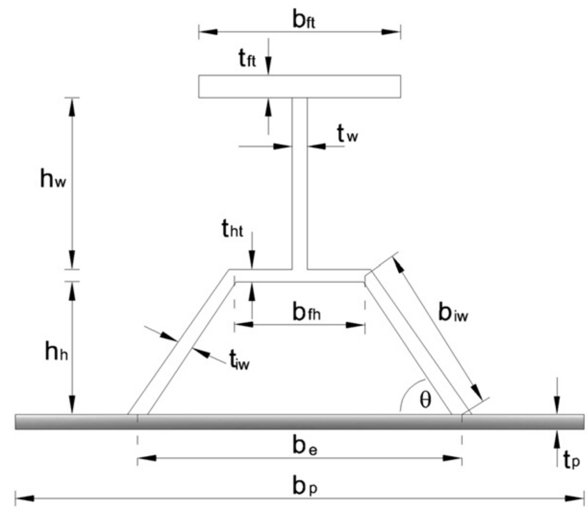

Fig. 2. Geometry of Y stiffeners.

Table 1
Dimensions of the standard T stiffeners.

Model	h_w	t_w	b_f	t_f	b_p	t_p	H_T
T1	300	12	150	15	850	15.5	330.5
T2	360	12	150	18	850	15	393
T3	400	12	150	18	850	17.5	435.5
T4	380	12	150	18	850	16.5	414.5
T5	330	12	150	15	850	15.5	360.5

All dimensions in mm, H_T is the total height of the T stiffener.

Table 2
Dimensions of the Y stiffeners in the first group.

Model	h_w	t_w	b_f	t_f	$t_{fh}=t_{iw}$	b_{fh}
Y1	360	5	210	8	9	71
Y2	342	6	300	9	9	61
Y3	400	5	330	8	11	60
Y4	361	5	345	8	10	58
Y5	330	5	323	7	9	83
Model	b_{iw}	h_h	b_{bh}	t_p	b_p	H_Y
Y1	100	66	213	17	850	421
Y2	107	71	213	15	850	446
Y3	108	71	213	18	850	507
Y4	109	77	213	17	850	473
Y5	91	60	213	16	850	422

All dimensions in mm, H_Y is the total height of the Y stiffener and $\theta=45^{\circ}$, $t_{fh}=t_{iw}$.