



OTC 20001

## Parametric Study of Ice Class Ship Structure

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### Abstract

The new IACS Polar Rules for Ships contain plastic limit state models of frame capacity. Those limit states were analytically derived using relatively simple energy methods, validated by finite element analysis. This paper examines an expanded range of frames and employs a technique called Design of Experiments (DOE) and non-linear finite element analysis to examine the plastic capacity of frames. The results are compared to the IACS Polar Rule limit states. The paper may serve as the basis for discussing an update of the Polar Rules. The paper also provides owners/designers/regulators with a methodology to examine a wide variety of alternative plastic designs within a broad design space.

### Introduction

Stiffened plates are the basic structural building blocks of many onshore and offshore structures, where high strength to weight ratio is a major criteria dictating design. The behavior of stiffened plate in the elastic region is well understood. In the recent years there has been a renewed interest in estimating plastic response of ship structures.

Ship design rules are changing from traditional working stress approach to new rules which allow plastic limit states, particularly in the case of ice class vessels. The rationale behind this move is the recognition that structure tends to have a large reserve capacity after it yields and before it finally collapses.

The capacity of a frame is currently estimated using the IACS rules. The pressure causing collapse in the case of a beam fixed at two ends and loaded at the center is given by IACS Polar Rules as (Daley, 2000):

$$P_{3h} = \frac{(2 - kw) + kw \sqrt{1 - 48 \cdot Zpns \cdot (1 - kw)}}{12 \cdot Zpns \cdot kw^2 + 1} \cdot \frac{Zp \cdot \sigma_y \cdot 4}{\left[ S \cdot b \cdot L \cdot \left( 1 - \frac{b}{2 \cdot L} \right) \right]} \quad (1)$$

$$P_{shear} = \frac{2A_w \sigma_y}{\sqrt{3}Sb} \quad (2)$$

The above pressure reflects the onset of significant plastic deformation and it ignores contributions from large deformations and membrane stresses. Hence the analytical solutions may not accurately estimate capacity of all frames. The reliable methods to estimate capacity are either to conduct a full scale experiment or a nonlinear finite element analysis. These methods are either very expensive or too complex. There is a need for a simple regression equation which can predict capacity taking into account all the non linear behavior of the structure.

There are ten factors which influence load carrying capacity of a frame. The study the effect of ten factors at two levels (high and low values of each factor) requires 1024 ( $2^{10}$ ) Finite Element Analyses. Considering the time required solving non-