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On the structural behavior of ship's shell structures due to impact loading

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Abstract

When collision accident between ships or between ship and offshore platform occurs, a common phenomenon that occurs in structures is the plastic deformation accompanied by a large strain such as fracture. In this study, for the rational design against accidental limit state, the plastic material constants of steel plate which is heated by line heating and steel plate formed by cold bending procedure have been defined through the numerical simulation for the high speed tension test. The usefulness of the material constants included in Cowper—Symonds model and Johnson—Cook model and the assumption that strain rate can be neglected when strain rate is less than the intermediate speed are verified through free drop test as well as comparing with numerical results in several references. This paper ends with describing the future study.

Keywords: Shell structure; Line heating; Impact loads; Fracture; Cowper—Symonds model

1. Introduction

Among marine accidents, ship collision takes about 35% of the entire marine accidents (for example web site of KOEM). Especially in case of a ship carrying detrimental liquids or oil crash, strand or explode, the leak of its pay load causes serious marine pollution. And it would cause huge environment and property loss as well as life. Estimation of structural damage due to collision accident is not easy due to variety in damage and fracture types during collision, different capacity in energy absorption and so on (Choung, 2007; Choung et al., 2011). Common phenomenon during collision and grounding accident is the plastic deformation accompanying large deformation such as fracture. Until recently many researches are carried out to achieve the structural design such that the structural undergoes minimum fracture but maximum deformation to absorb the external energy.

Collision and grounding accidents can be categorized into the internal and the external mechanics. The external mechanics has concerned with the estimation of kinetic energy of striking and struck structures, and the internal mechanics has concerned with the dissipated energy due to plastic deformation during collision and grounding. The study on the internal mechanics of collision accident was initiated by Minorsky (1958) and many researches have been carried out in the past few decades. Amdalh (1983) conducted collision test for the bow structure by scaling down and simplifying bulbous bow structures as tubes with circular and elliptical cross-section, and proposed the simplified formulae of estimating crash strength. Numerical simulation methods have been also proposed (for example, see Wisniewski and Koiakowski, 2003).

Regarding the fracture criteria, in most studies shear fracture criterion is used in dealing with the collision, contact and grounding problems. Lehmann and Yu (1998) proposed the effect of stress tri-axiality on the fracture based on the fracture mechanics of continuum, and Urban (2003) proposed RTCL model (Rice-Tracey and Cockcroft-Katham model) for the fracture criterion. The common point of these works is that

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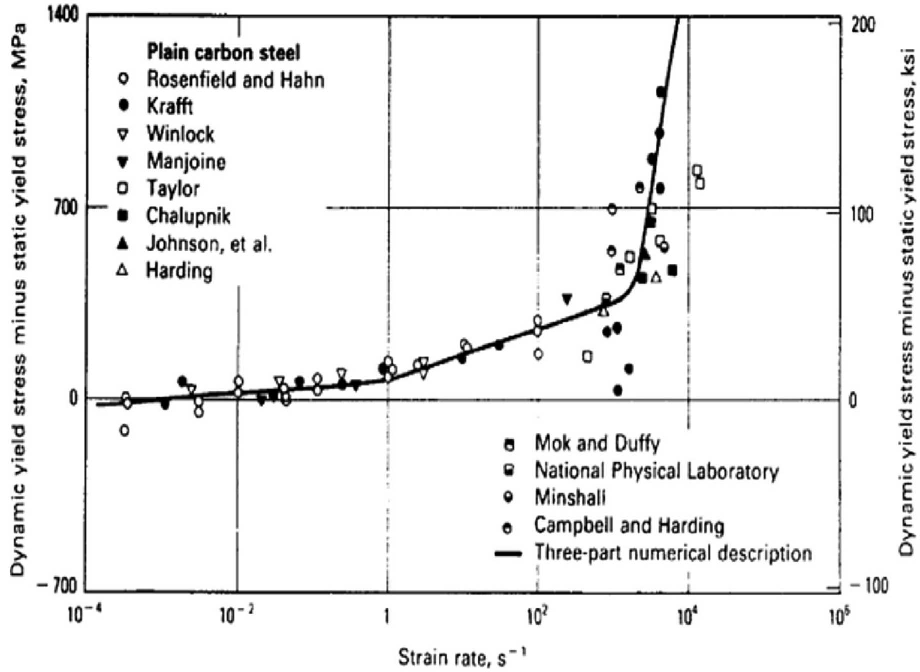

Fig. 1. Dynamic yield stress to strain rate (Meyers, 1994).

fracture behavior of material was affected by the stress triaxiality. Recently Choung (2007) presented the plastic and fracture characteristics of marine grade steels through test and numerical studies. However, in most research, material properties obtained based on results of tensile test for the material without heat treatment have been used. The estimation of damage of striking structure as well as struck structure as accurate as possible is one of the most important tasks for a more rational design. Rare study is concerned with the plastification or fracture characteristics of curved outer shell form by heat treatment such as line heating, triangular heating and so on. As it is well appreciated, heat forming method usually used in manufacturing the curved blocks frequently found in bow and stern part of a ship, and much heat is inputted during heat forming process. The outer shell plates in bow or stern part of ship usually formed by cold bending process using press followed by heat forming process using line heating, triangular heating and so on. Many researches have been carried out to investigate the physical phenomena or to develop the formulae of predicting thermal deformation of line or triangular heating method (see for example Ha 2001; Jang et al., 2001; Lee et al., 2002; Shin, 1992).

This study is concerned with investigating plastic material properties of ship's outer shell plate formed by the heating process aimed at a more rational design against the limit state under marine accident. For the present study, the elasto-plastic properties of marine grade steel suggested by Lim (2012) based on the results of line heating and tension test are used, which was the preceded study of the present paper. According to the results of the preceded study (Lim, 2012), material strength of heated steel increased due to hardening effect of heat process but true fracture strain decreased due to hardening effect. And also it was found that energy absorbing capacity became very much lower than the unheated steel. This may be disadvantage from view point of the ultimate limit state design.

This study is, hence, mainly concerned with the dynamic fracture due to impact load such as collision force of heated steel by line heating method. This paper first presents two typical models of strain equations for the Cowper—Symonds and Johnson—Cook models, and reviews the material constants included in the Cowper—Symonds model through related references. In analyzing the highly dynamic problem such as structural analysis of collision accident, dynamic material properties obtained through high speed tension test are very important. But in case of marine grade steel, there is not much information available about the dynamic material properties, especially there are rare information about the dynamic material properties for the heat treated steel by thermal process such as line heating. In this study, the dynamic material properties have been obtained through the numerical simulation of dynamic tension test of which validity has been verified in the proceeded study. With the results of this

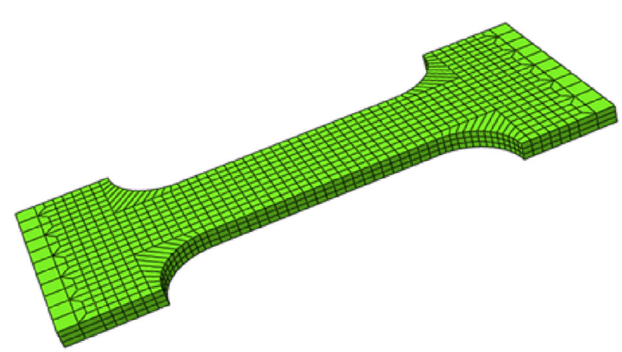

Fig. 2. Finite element model for numerical simulation of tensile test.