



Fracture analysis and constitutive modelling of ship structure steel behaviour regarding explosion

A.-G. Geffroy^{a,b,*}, P. Longère^a, B. Leblé^b

^aUEB/UBS/LIMATB, Centre de Recherche Christiaan Huyghens, Rue de Saint Maudé, 56321 Lorient Cedex, France

^bDCNS, Rue Choiseul, 56311 Lorient Cedex, France

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ABSTRACT

Consistent constitutive modelling of material behaviour and further reliable numerical prediction of the response of structures under severe loading necessitate the knowledge of the microstructural mechanisms at the origin of failure.

The present work deals notably with the identification of the microstructural damage mechanisms of a high purity (ferritic–pearlitic) mild steel employed as structural material in military ship building. With this aim in view, an extensive campaign of experiments has been carried out, including interrupted and until fracture tests on smooth and notched, axisymmetric and plane specimens. Initial and post-mortem microstructures of the samples have been observed using a scanning electron microscope (SEM) in order to reveal the damage mechanism. The latter is double: quasi spherical cavity nucleation and growth inside the soft ferritic matrix and microcracking at the (soft)ferrite–(hard)pearlite interphase. Conditions for initiation and evolution of these two kinds of damage appear as being different as expected. The various steps of diffuse damage, microcracking and macro cracking yielding ultimate failure are also observed. Fractographies obtained from tensile tested samples and explosion loaded plates are also compared.

Moreover, the material behaviour has been modelled, describing the salient effects observed experimentally, namely strain and strain rate hardening, and thermal and damage softening. The parameters identification was accomplished using an inverse method based methodology. Finite element numerical simulations involving far-field underwater explosion loading implemented as user subroutine in the FE computation code ABAQUS has also been performed, leading to a satisfying agreement between experimental and numerical results.

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1. Introduction

Designing military ship structures, as surface ships or submarines, imply to consider, in addition to conventional sailing stresses, vulnerability related conditions. The context of the present work is mainly concerned with ship structure vulnerability regarding explosions with the aim to preserve the sailing functions of the ship and the integrity of sensitive areas. A way to minimize the damage induced by underwater explosions is to consume the energy of the explosion by plastic deformation of the structure. The fracture of the external panel is tolerated, but integrity of the internal panel has to be preserved.

* Corresponding author at: UEB/UBS/LIMATB, Centre de Recherche Christiaan Huyghens, Rue de Saint Maudé, 56321 Lorient Cedex, France. Tel.: +33 (0)2 97 87 46 44.

E-mail addresses: anne-gaelle.geffroy@univ-ubs.fr (A.-G. Geffroy), patrice.longere@isae.fr (P. Longère), bruno.leble@dcnsgroup.com (B. Leblé).