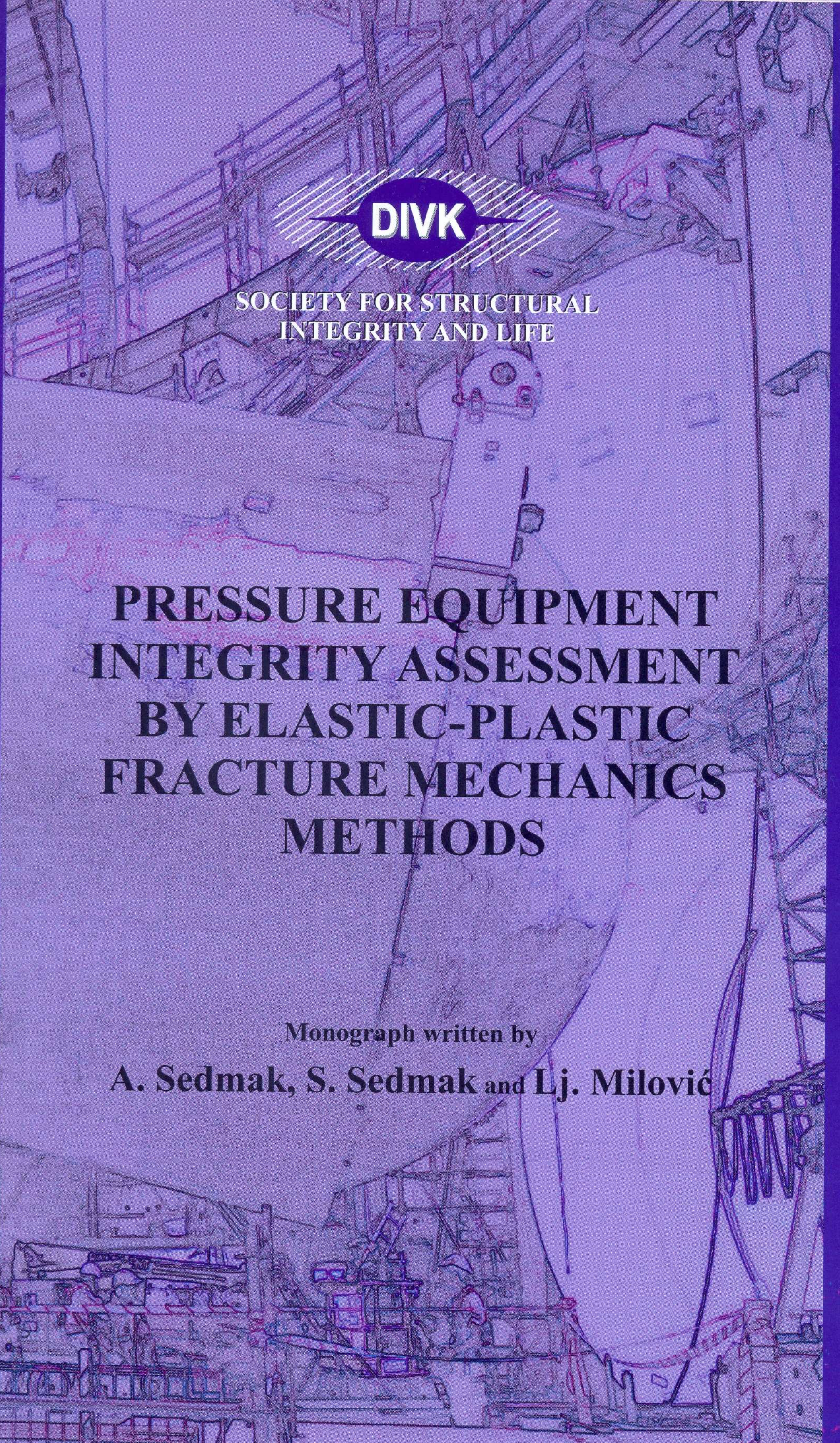

DIVK

SOCIETY FOR STRUCTURAL
INTEGRITY AND LIFE

PRESSURE EQUIPMENT INTEGRITY ASSESSMENT BY ELASTIC-PLASTIC FRACTURE MECHANICS METHODS

Monograph written by

A. Sedmak, S. Sedmak and Lj. Milović

Published by the
Society for Structural Integrity and Life (DIVK),

Reviewed by:
Prof. Dr. Todor Adžiev
Prof. Dr. Nenad Gubeljak

First edition 2011
Circulation:
400 copies

Printed by
Faculty of Tehnology and Metallurgy,
Research and Development Centre of Printing
Karnegijeva 4, Belgrade, Serbia

To contact the Publisher
DIVK (Society for Structural Integrity and Life)
Bul. Kraljice Marije 16
11000 Belgrade, Serbia
E-mail: asedmak@mas.bg.ac.rs

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

620.172.24:62-988
539.42

SEDMAK, Aleksandar, 1955-
Pressure Equipment Integrity Assessment by Elastic-Plastic Fracture Mechanics Methods / Monograph Written by A.[Aleksandar] Sedmak, S.[Stojan] Sedmak and Lj.[Ljubica] Milović. - 1st ed. - Belgrade : Society for Structural Integrity and Life, 2011 (Belgrade : Faculty of Technology and Metallurgy, Research and Development Centre of Printing Technology). - 294 str. : ilustr. ; 24 cm

Tiraž 400. - Bibliografija uz svako poglavlje. - Registar.

ISBN 978-86-905595-1-0
1. Sedmak, Stojan [аутор], 1929- 2. Milović, Ljubica, 1965- [аутор] a) Опрема под притиском - Интегритет b) Механика лома
COBISS.SR-ID 181732364

CONTENT

PRESSURE EQUIPMENT INTEGRITY ASSESSMENT BY ELASTIC-PLASTIC FRACTURE MECHANICS METHODS

PREFACE

The general term "pressure equipment" comprises a series of object operating under pressure, produced for different functions. Their application is very extended, as the components (pressure vessels, reformers, converters, boilers, heat exchangers, storage tanks, pipelines) in various systems, like chemical process industry, power and heat production and distribution, water supply. They are also important components of transportation means, in buildings and in household application and have an important role in everyday human life. Safe and reliable operation of pressure equipment is condition for their effective use.

In this monograph only most general approaches are considered, and selected case studies from the experience of authors are presented as examples, with the aim to give the details not frequently available in references.

Pressure equipment presents one of the most important objects in industrial development. Today it is impossible to imagine the life without electrical energy, oil and gas. For oil and gas transportation several thousands kilometers long pipelines under pressure are constructed all over the world. They are disposed as over ground, through inapproachable regions and terrain, but also as under ground and sea. Electricity is produced in power plants, in which the basic equipment are components operating under pressure, like boilers and heaters in fuel fired and nuclear plants, or penstock in hydroelectrical power plants. Process plants and oil refineries are composed of different closed apparatus, converters and devices operating under pressure, which are connected by pipelines for a continuous production. District heating in the cities is possible due to developed net of pipelines for energy (heat) distribution, but also using convenient equipment for energy production, like boilers. Pressure vessels are present in domestic economy and farms as vital devices, i.e. boilers or gas holders. In transportation means (cars, tracks, trains, planes, ships), pressure equipment has to be applied.

It is to underline that this development involved new serious problems closely connected with environment protection, from two essential reasons. First one is environmental pollution through the operation of industrial plants and all participating sectors in human community, like traffic. The second one is related to failures of pressure equipment, often with catastrophic consequences. It became clear that knowledge and experience in the time of design and manufacturing of machines and equipment are not sufficient to satisfy all needs. The development of materials was behind the design requirements in many senses. The experience how to use new product in economic, safe and reliable way was poor. One may claim that in spite of huge progress of engineering the situation is still similar to that from early beginning in industrialization because each new development opened new problems due to decent knowledge and problem understanding, forming in this way a specific spiral in competition of knowledge and desired design. Available knowledge enables colossal products like huge buildings, large ships, airplanes of unbelievable size, thousands kilometers long pipelines, and on the opposite side nanostructures, still under intensive development. But it is likely that there are not limits in knowledge and development. Although there is no end in size of super great and super small products, on both sides necessary knowledge and skill must be under steadily progress. Structural integrity is a inevitable common denominator for both classes, giant and nano structures.

Engineers and scientists succeeded to improve basically the situation regarding structural integrity by introduced directives, recommendations, codes, regulations and standards, requested and applied in design, manufacturing, exploitation, inspection and maintenance. Today, in pressure equipment domain two basic documents, European directives and SINTAP, are developed to assure the quality, necessary for safe and reliable exploitation.

Pressure equipment, operating at different pressure levels, many of them also at different temperatures, from extremely high to very low, are exposed to different loading, working condition and environment. For that, their failures are not a rare event, and depending on loading and environment condition these failures can be catastrophic. Let us just mention the disaster in Bopal (India) in 1984, with several thousands killed people, accident in Three Miles Island (USA) and Chernobyl (Ukraine) nuclear plants, as well known. Also to add last incident in Fukushima (Japan) with earthquake and forced tsunami of non predicable level of severity, that destroyed attacked region and produced catastrophic failure in a nuclear power plant. Such a severe failure could not be predicted by the available knowledge when plant was designed and constructed.

In all economy branches failures of pressure equipment occur every day, in spite strict regulations, codes and directives prescribed and applied from the very early stage in design up to the end of equipment life. The consequences can be different, from negligible up to the cases with many victims and injures, followed by material loss.

This serious problem attracts the attention, directed in the first line to prevent the failure occurrence, or to reduce the significance of caused damage. However, the problem is extremely complex due to numerous influencing factors, acting from design in all stages of equipment life. Each of influencing factors requires detailed analysis and the experts of different kinds have to be engaged to solve the problem. For that, the basic approach to pressure equipment structural integrity assessment is based on experience from the analysis of case studies, but still asking for supports of scientists in theoretical consideration. That means developed new theories have to be adapted to real situation found in considered pressure equipment in order to derive the proper solution for each case. This is also the case with fracture mechanics, developed in the middle of last century based on analysis of crack behavior in a body. Before fracture mechanics the designed components were considered as of regular geometry shape and material of the component was treated as continuum of homogeneous properties, having in mind the basically mathematical approach. Since this was not so in real developed structures, the necessary approximations and simplification were involved, and many correction factors had been accepted in engineering application, that means again experience get the most important role in machine design, including pressure equipment considered in this monograph. On the other hand, extended use of pressure equipment posed more strict requirement regarding material properties and manufacturing technologies, introducing in design and production of new, uncertain and non experienced tasks. This process is still in development, and still asking the help of theoretical approach, in addition to broadly applied modeling and numerical analysis using computers and software of high capacity. Nano structure, nano technologies and nano materials can serve as a proof for this, because the rules and equations derived for crystalline metallic material are no more completely applicable at nano level. New experience is required, but again it has to be gathered from already existing development, experiments and theory. Here also must be mention important help obtained using computers and developed software in numerical calculation and processes modeling.