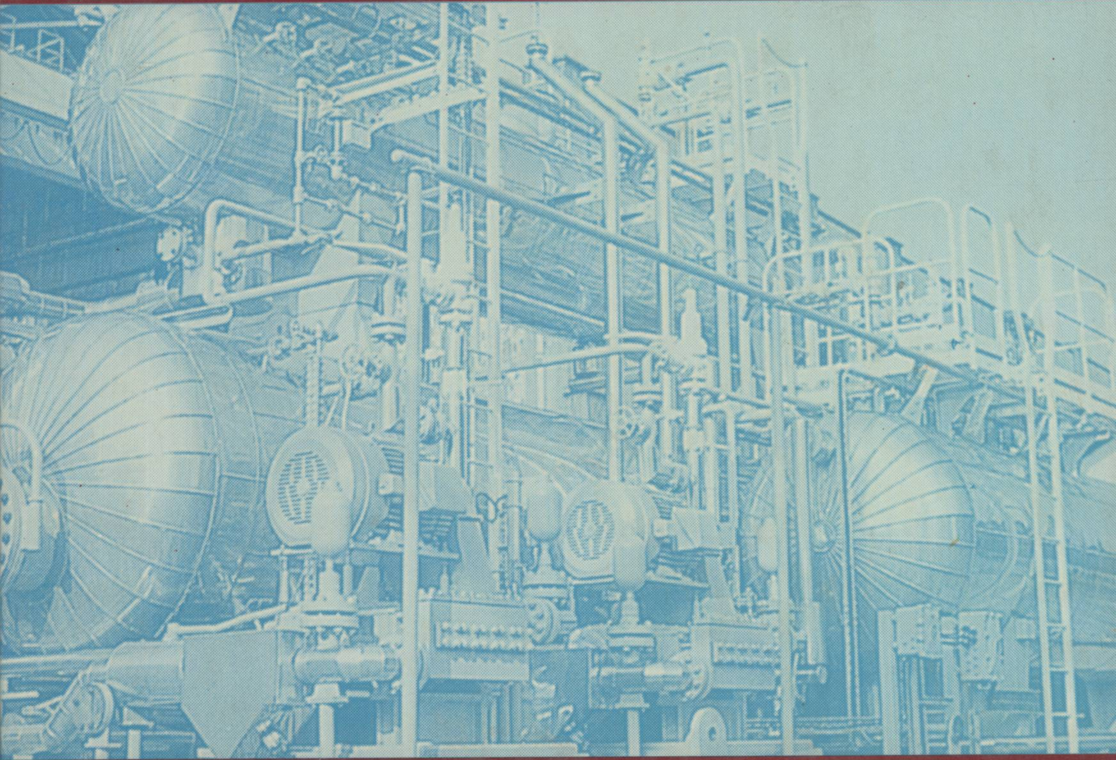
PRESSURE VESSEL AND PIPING TECHNOLOGY



Editors

John S. T. Cheung and L. S. Ong

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Nanyang Technological University
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PRESSURE VESSEL AND PIPING TECHNOLOGY

Proceedings of the Seminar on "Pressure Vessel and Piping Technology" held at the Marina Mandarin Hotel, Singapore, 24 & 25 May 1993.

Seminar Organiser: School of Mechanical and Production Engineering, Nanyang Technological University, Singapore 2263.

Seminar Co-sponsors:

American Society of Mechanical Engineers, Pressure Vessels and Piping Division, USA

The Institution of Mechanical Engineers, Pressure Systems Group, UK

The Institution of Engineers, Singapore

American Society of Mechanical Engineers, Singapore Chapter

Institute of Materials, East Asia Chapter

Singapore Welding Society

Singapore Structural Steel Society

Society of Loss Prevention in the Oil, Chemical and Process Industries, Singapore

Society of Naval Architects and Marine Engineers, Singapore

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Dedicated to the late Professor Leung Shiu Kee
Dean, School of Mechanical & Production Engineering,
Nanyang Technological University, from 1981 to 1992.

PREFACE

This book records the proceedings of the Seminar on Pressure Vessel and Piping Technology held in Singapore on the 24th and 25th of March 1993. The fact that the seminar speakers and participants come from many Asian countries and beyond reflects the newly established position of Singapore as an engineering centre serving the oil, gas, petrochemical and power industries of the Asia-Pacific Rim.

The seminar organiser is the School of Mechanical and Production Engineering of Nanyang Technological University (NTU), Singapore, which has a tradition of being the university of the industry. Arising from its applied research interests in pressure vessel and piping technology, the School has been organising continuing education short courses on this technology since 1986. Although this outreaching activity has a short history, its growth has been rapid in terms of number, scope as well as depth. Currently such short courses attract participants from many neighbouring countries and the course instructors include professors and engineering specialists from not only Singapore but also UK and USA.

It is against this background of active involvement in pressure vessel and piping technology that the School decided to extend its research and continuing education activities to organising this industrial seminar. Speakers and participants were invited from Asia and beyond. Based on our contacts and recommendations, a number of engineers societies were invited to co-sponsor the Seminar, and a number of engineering managers and academic administrators were invited to be its advisors. The NTU organizing committee is grateful for their assistance and their support. Significantly, the co-sponsorship from both the Pressure Vessel and Piping Division of the American Society of Mechanical Engineers, and the Pressure Systems Group of the Institution of Mechanical Engineers, UK, has helped very much to raise the platform of this seminar into the international arena.

Since the practice and developments in pressure vessel and piping technology in the USA are well-known and well-documented, we decided to invite keynote papers presenting specific new developments in China and Europe. One keynote speaker, Professor Cengdian Liu, is the immediate past President of the Chinese Pressure Vessel Institution and a member of the International Council on Pressure Vessel Technology. The other keynote speaker, Dr Steve J Garwood, is the Head of Engineering at the Welding Institute, UK, and a member of more than one British Standard Pressure Technical Committee.

In producing this proceedings, we are appreciative of the support of the management and staff of the publisher which is a fast growing Singapore based multinational company. We also wish to thank the staff of the NTU Continuing Education Centre for their enthusiastic assistance in organising the Seminar.

John S. T. Cheung
L. S. Ong

CONTENTS

KEYNOTE PAPERS

THE PRACTICE OF DEFECT ASSESSMENT FOR PRESSURE VESSELS IN CHINA

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ABSTRACT

Since the NDT technique has been and is developing quickly, more defects have been detected in in-service inspections. Due to difficulties in implementing on-site repair welding to some pressure vessels, the practical use of defect assessment using fracture mechanics in China has been and is being carried out on a large scale since the early seventies. Applications of fracture mechanics to the defect assessment of pressure vessels with defects in the weldments have resulted in large economical returns. Some case studies are cited in this paper as illustrations.

KEYWORDS
Pressure vessel; Defect assessment; Fracture; Fatigue; COD; Misalignment; Angular distortion; Pit; Failure assessment diagram.

1. Introduction

The number of pressure vessels now in-service in China amounts to approximately one million, not counting portable ones. In China, the application of fracture mechanics to defect assessment of pressure vessels was started in the early seventies. Due to the fact that it is difficult to implement repair welding to some pressure vessels on site, the defect assessment for pressure vessels has been widely carried out. In the late seventies, a series of standards was issued in China on test methods for the determination of fracture toughness and fatigue crack growth rate of metallic materials[1-4], which has laid a foundation to compile a guidance document on defect assessment of pressure vessels. A working group organized by the General Machinery Research Institute (under the Ministry of Machinery and Electronic Industry) and the Chemical Machinery Research Institute (under the Ministry of Chemical Industry), after carrying out research on Pressure vessels with defects for several years, issued a guidance document known as "Rules for the Assessment of Defects in Pressure Vessels, CVDA-1984"[5] in 1984. In the document both methods of stress intensity factor and COD are adopted to assess the defects. A new guidance document on the defect assessment of pressure vessels is being under compilation in China to utilize fully the 20-year experience on assessment of defects and also the recent advances of pressure vessel defect assessment technology in other countries. In the new rule it is intended to consider the use of failure assessment diagram (FAC).

In China, to carry out the assessment, special attention is paid to the reliability of non-destructive testing. In this connection, for pressure vessels of importance, the NDT should as a rule be done independently by two or more separate certificated inspectors. The results are then compared and checked for accuracy. As the implementation of defect assessment of pressure vessels is a technical problem with complexity, in China only a few qualified research institutes are permitted to carry out the assessment.

It is intended in this paper to cite a few examples of successful assessment which resulted in a tremendous saving of money. In view of insufficient experiences to implement defect assessment and in order to insure safe operation of pressure vessels, the assessments carried out in China are all on the conservative side, especially in the early stage.

2. Defect Assessment of Spherical Pressure Vessels

It was found after completing fabrication, on the surface of weldments of four 1900 m^3 spherical pressure vessels intended to store ethylene built in 1974, there existed some thousands surface cracks with a depth >1 mm in total. The characteristics of these cracks showed that they are delayed cracks. Dimensions and operating conditions of spherical pressure vessels are: inside diameter 15.4 m, wall thickness 40 mm, design pressure 2.1 MPa, design temperature -31°C. Vessels were fabricated with RIVERACE 60L steel plates, the yield strength of which was 550 MPa. In view that there were too many cracks on the vessels, it was not practical to implement on-site repair welding. It was therefore decided to make defect assessment with the aid of fracture mechanics, which was carried out by the cooperative action of the experts of seven research institutes and universities[6].

2.1. Determination of Fracture Toughness

The crack initiation COD values of RIVERACE 60L, including the base metal, weld metal and the heat affected zone were measured. For the sake of safety, the crack initiation COD value used in the assessment was the lowest value of $\delta_c = 0.06$mm.

2.2. Determination of Bending Stresses Caused by Angular Distortion and Misalignment

Angular distortion and misalignment were unavoidable during the fabrication of spherical pressure vessels, which were the sources of great bending stresses. It was difficult to attack this problem with theoretical exact solution. Simplifications were made in the engineering application with the aid of the model shown in Fig.1.

The following equations may be used to calculate the additional bending stresses due to angular distortion and misalignment.

$$\sigma_b = \frac{6\,(K_w \cdot W + K_d \cdot d)}{t}\,\sigma_m \qquad (1)$$

$$K_w = \frac{1}{2}\tan\frac{m}{2} \quad (2)$$

$$m = \sqrt{3(1-\nu^2)\frac{\sigma_m}{E}\left(\frac{L}{t}\right)} \quad (3)$$

$$K_d = \frac{\sinh\lambda m[m\cosh(1-\lambda)m - \sinh(1-\lambda)m - m\lambda]}{m\lambda(1-\lambda)(m\cosh m - \sinh m)} \quad (4)$$

(Note: See end of paper for nomenclature.)

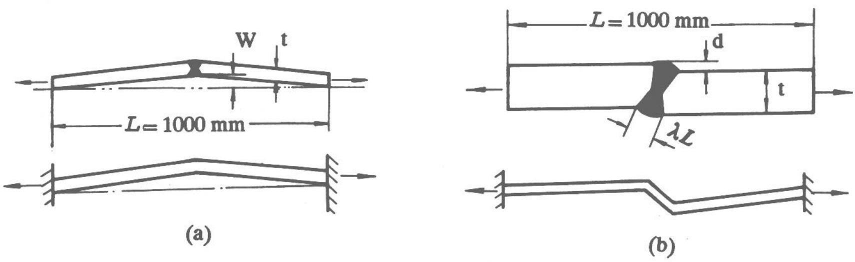

Fig.1. The model of angular distortion and misalignment
(a) Angular distortion (b) Misalignment

As the derivation of the above equations is based on a simplified model of clamped support beam, it is not on the safe side. That is why a value greater than the actual value of angular distortion was taken during calculation, say W=15 mm. Value of σ_b calculated is 314 MPa.

2.3.The proper Selection of a Magnetic Particle Testing Method

To detect shallow surface cracks on a spherical pressure vessel, magnetic particle testing was used. Because it was quite dark inside the spherical pressure vessel, it deemed necessary to select proper magnetic particle for this purpose. To facilitate comparison, the same testing team used both black magnetic particle testing and fluorescent magnetic particle testing. To the welds of total length of about 50 m, testing was first made with black magnetic particles and then with fluorescent magnetic particles. Results of testing are shown in Table 1. Which clearly shows, the detectibility of the fluorescent magnetic particle testing is far higher than the black magnetic particle testing.