STP-PT-031

PRESSURE INDUCED FATIGUE

ASME STANDARDS TECHNOLOGY, LLC

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FOREWORD

This document was developed under a research and development project which resulted from ASME Pressure Technology Codes & Standards (PTCS) committee requests to identify, prioritize and address technology gaps in current or new PTCS Codes, Standards and Guidelines. This project is one of several intended to establish and maintain the technical relevance of ASME codes & standards products. The specific project related to this document is project 07-06 (B31#3), entitled "Pressure Induced Fatigue."

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ABSTRACT

The purpose of this study is to begin the process of developing an appropriate and accurate method of predicting fatigue failure due to internal pressure loading in piping components. Historically, piping component fatigue has been analyzed using the approach of Markl [1]. The results from the cyclic pressure testing of 41 piping intersections have been evaluated. The fatigue results were found to follow the Markl type power law relationship with some considerable scatter. The scatter observed in the data is attributed to variation due to the nature of fatigue failure in large welded structures. It is further concluded that several design curves are appropriate for use as a design rule for pressure induced fatigue.

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1 INTRODUCTION

Several recent failures in welding tees and branch connections in B31.1 piping due to pressure cycling have been brought to the attention of the B31.1 committee. In addition, there has been a long-standing agenda item on the B31 Technical Committee on Mechanical Design (MDC) to develop stress multipliers of some sort for fatigue evaluation of piping components due to pressure cycling. The fatigue performance of piping components has been well understood in terms of thermal expansion stresses (i.e., secondary stresses), but the fatigue performance due to pressure cycling has been less understood. With the relatively high D/t ratios of high temperature power and process piping, fatigue due to pressure cycling is generally less significant than fatigue due to thermal expansion. However, as the pressure technology codes and standards use higher and higher strength materials (resulting in thinner components) and operate at higher and higher pressures (e.g., hydrogen for fuel technology), the cycling effect of pressure is expected to be much more pronounced.

The purpose of this study is to begin the process of developing an appropriate and accurate method of predicting fatigue failure due to internal pressure loading in piping components. Historically, piping component fatigue has been analyzed using the approach of Markl [1]. Fatigue life is accounted for by using a power law relationship between the applied loading stresses and life in the form:

$$C = iSN^{0.2} \tag{1}$$

Where N is the fatigue life of the component, C is a material constant, i is the stress intensification factor and S is the nominal applied stress. This equation assumes a linear relationship between Log(S) and Log(N) as has been observed in rotating beam fatigue tests in steels. The exponent value of 0.2 was used based on the experimental observation for steel, and Markl suggests an appropriate value for C is 245 ksi for welded carbon steel.

For pressure-induced fatigue, the nominal applied stress is the tangential stress in the pipe due to internal pressure and the stress intensification factor (now defined as i_p) is experimentally determined through actual fatigue testing of piping components. It has been thought that experimental development of i_p is superior to analytical methods since the actual components are welded engineering structures and the loading actually developed in the welded structure may not be well described by a continuous homogeneous model that could be used to generate theoretical stresses. Therefore, i_p is determined for a given pipe intersection by performing two fatigue comparative fatigue tests on a welded pipe without the pipe intersection and also on a pipe with the intersection in such a manner to produce the same fatigue life. The value of i_p is the ratio of the nominal stress in the pipe without the piping intersection to the nominal stress in the pipe with the piping intersection. The purpose of this study is to develop a plan and estimate the cost of performing such a test plan that will result in the determination of i_p. However, based on the findings obtained, it may not be necessary to perform a testing program since there appears to be sufficient existing data and analysis that adequately describe the fatigue performance of pressure loaded pipe intersections.