International Journal of Offshore and Polar Engineering
Vol. 9, No. 1, March 1999 (ISSN 1053-5381)

Application of the Pivot Point on the FCP Diagram to Low-Temperature Fatigue of Materials

Meng-Lan Duan
China Classification Society, Beijing, China

James C.M. Li and Jing Li
University of Rochester, Rochester, New York, USA

ABSTRACT

By analyzing the test data of the fatigue crack propagation in offshore structural steel A537 at room and lower temperatures, a pivot point on the FCP diagram is presented, from which a relationship of m–ln$C$ is derived, where m and C are the constants in the Paris Equation. The derived m–ln$C$ relationship for steel A537 is identified with a group of reports on the existence of an experimental m–ln$C$ relationship from the literature. From the discussion and assessment of the m–ln$C$ relationship, a critical stress intensity factor range named ΔK_{pc} is proposed. Hence, ΔK_{th}, ΔK_{pc} and ΔK_{fc} represent different fatigue crack propagation stages, and ΔK_{pc} can be used as a low-temperature fatigue safety index that is very important in monitoring the safe propagation of fatigue cracks and also important in evaluating the low-temperature properties of materials.

NOMENCLATURE

a, b, B	:	material constants
da/dN	:	fatigue crack growth rate
ΔK	:	stress intensity factor range
ΔK_{th}	:	threshold stress intensity factor range
ΔK_{pc}	:	ΔK value at pivot point
ΔK_{fc}	:	critical ΔK value at which unstable propagation of crack begins
m,C	:	Paris constants
m_i,C_i	:	Paris constants at temperature T_i
$(da/dN)_{pc}$	:	fatigue crack growth rate at pivot point
T, T_i	:	temperature
$U(\Delta K)$	:	a crack closure function

INTRODUCTION

The offshore petroleum platforms in Bohai Gulf, China, experience low temperatures that fall as low as 238K for 3 months in winter. Cracks in the structures have to withstand low-temperature fatigue and unstable propagation of fatigue cracks, or brittle fracture would occur most possibly. Under ice loading, the shortest estimated fatigue life of an offshore platform by use of S–N curves is only 2 years. The study of low-temperature fatigue of offshore structures under ice loading is getting more and more urgent with the large-scale exploitation of offshore oil in Bohai Gulf. Fatigue tests on the offshore structural steels are the basic part of this study. Steel A537 is the main structural steel of the offshore tubular joint platforms in Bohai Oil Field and has to be tested for withstanding both low temperatures and ice loading. This paper is the extension of work by one of the authors (Duan, 1995; Fang and Duan, 1992).

Received February 12, 1997: revised manuscript received by the editors December 16, 1998. The original version was presented directly to the Journal.
KEY WORDS: Fatigue crack propagation, low-temperature fatigue, pivot point, Paris constants, stress intensity factor range.

RESULTS OF FATIGUE CRACK PROPAGATION TESTS ON STEEL A537

Fatigue crack propagation tests on steel A537 at room and lower temperatures were partly reported (Duan, 1995; Fang and Duan, 1992). The chemical composition and mechanical properties of steel A537 are shown in Table 1 and 2, respectively. Here is a list of the test results, which are also schematically presented in Fig. 1:

1) The threshold value of fatigue cracks in steel A537 and crack propagation resistance near the threshold region increase with the decrease of temperatures.

2) The stable fatigue crack propagation in steel A537 follows the Paris law, but the Paris exponent m varies with temperatures, presenting a much larger value at lower temperatures.

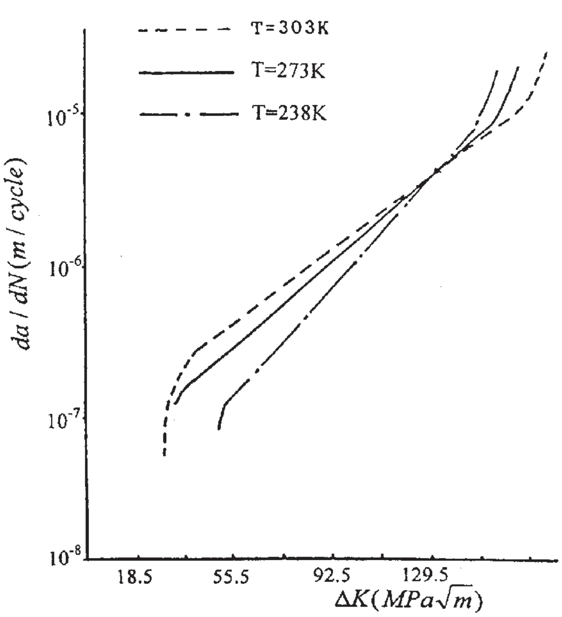

Fig. 1 FCP diagram of steel A537 at different temperatures