S-N Fatigue Design Guidelines and Test Data for Low-alloy Steel Bolts

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001, standards@api.org.

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Introduction

The requirements for bolting fatigue assessment were a charge of the API CSOEM Multi-Segment Task Group on Bolting Failures. Due to documented subsea bolting failures defined in the BSEE QC-FIT Evaluation of Connector and Bolt Failures, the charge of the sub task group TGR-13 was the following:

"*Guidance should be issued by API on when and how to perform fatigue sensitivity analysis on bolting*."

API CSOEM Bolting Report for TGR-13 and TGR-14 was issued. It defined the design guidelines and provided recommendations for performing a full-scale fatigue testing on bolting. Upon further approval, full-scale fatigue testing was performed.

The following guidelines are provided for both design verification fatigue analysis and corresponding full-scale fatigue testing that was performed.

Design verification analysis for fatigue assessment of bolting requires an evaluation for S-N or fatigue crack growth rate. The S-N fatigue evaluation can be based on either the stress concentrations of the thread profile, which will need stress amplification factor (SAF) or stress concentration factor (SCF) and smooth tensile bar S-N testing, or minimum root diameter stress without thread profile, which will need full-scale bolt fatigue tests. The basis of this document is the S-N approach using full-scale fatigue testing. The purpose of the full-scale bolt fatigue testing was to obtain S-N fatigue life for bolts manufactured to meet API 20E BSL-3 and the requirements for API 17D loading condition. The fatigue testing was based on alternating axial stresses in the bolt with a defined preload. The preload was applied with the load frame to a value of 2/3*YS based on the cross-section at the root radius of the thread. The defined bolt lengths represent API flange by flange connection conservative bolt lengths for a given bolt size. The bolt-to-nut thread engagement met the requirements of API 6A. Each bolt tested had two bolt/nut connections where the failure of the first connection was defined as the fatigue life.

The objective of the test program was to provide S-N fatigue curves for bolts that are preloaded to API Series 17 standards and are subjected to a range of alternating axial stresses. The preload and alternating stress ranges were defined based on the cross-sectional area at the root radius of the threads. The test program evaluated bolt size effects and environments of air and saltwater with cathodic protection (CP).

S-N Fatigue Design Guidelines and Test Data for Low Alloy Steel Bolts

1 Scope

The scope of the test program was to obtain bolting material fatigue data required to perform design verification analysis of fatigue-sensitive bolts to assure accurate design life estimation. The bolting fatigue testing program provided S-N fatigue curves for three alternating stress ranges in air and saltwater with CP and for bolt sizes of 1 in., 2 in. (Grade L7), and 3 in. (Grade L43).

The results of these S-N fatigue tests allow the bolting design to be assessed for S-N fatigue through structural analysis using the nominal root area stresses in the bolt, avoiding the need to define stress and load concentrations in the bolt root radius of engaged threads.

The design guidelines and the fatigue data provided in the document are intended to be used for bolting with unified national thread with root radius (UNR) specifications of ASME B1.1 class 2A/2B.

2 Normative References

There are no referenced documents that are indispensible for the application of this document.

3 Terms, Definitions, Abbreviations, and Symbols

3.1 Terms and Definitions

3.1.1
high-stress range fatigue cycles
HFC
Tested fatigue cycles to failure for a high-stress range or high force condition applied.

3.1.2
low-stress range fatigue cycles
LFC
Tested fatigue cycles to failure for a low-stress range or low force condition applied.

3.1.3
medium-stress range fatigue cycles
MFC
Tested fatigue cycles to failure for a medium-stress range or medium force condition applied.

3.1.4
stress range
The difference between the maximum stress and minimum stress being applied.

3.2 Acronyms, Abbreviations, and Symbols

CP	cathodic protection
EF	electric furnace
HFC	high-stress range fatigue cycles
FSF	full-scale fatigue
LFC	low-stress range fatigue cycles
MFC	medium-stress range fatigue cycles
MPS	manufacturing process specification