A Study of the Effect of Thread Forming on the Susceptibility of Precipitation Hardened Ni-Based Alloy Fasteners to Hydrogen Embrittlement

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Contents

Figures

Contents

Page

Tables

Introduction

This study was completed in response to recommendations by API to investigate and quantify the relative hardness of threaded precipitation hardened nickel-based alloys (PHNAs), by both machined and cold rolled methods. This study also aligns with recommendations issued by the API Multi Segment Task Group on Bolting Failures (February 29, 2016), where it was concluded that “Product subcommittees should review and consider … resolving existing conflicting properties specified in product specifications …”. The information in this technical report has not been readily available as existing public or industry data.

Industry specifications often require hardness testing of PHNAs used for bolting in their final process condition, i.e. after all heat treatments, secondary processing, and machining. Threads, however, can be cold rolled into the product, which is a form of secondary processing that cannot be routinely tested for material properties. Further, cold rolling is a form of strain hardening, which increases hardness in the affected area. This can result in conflicting requirements or industry specification interpretation differences of requirements, which can be problematic with respect to specification compliance.

Due to the general nature of hardness and microstructure impact on susceptibility of materials to hydrogen charging environments, additional hydrogen embrittlement incremental step load testing (i.e. a fracture mechanics-based approach) was also performed. Novel specimen geometries were used for accurate assessment of both machined and cold rolled threads, and the results compared with bulk material properties.

The PHNAs studied in this program were alloy 718–120k (UNS N07718), alloy 718–150k (UNS N07718), alloy 725–120k (UNS N07725), and alloy 945–120k (UNS N09945). All materials tested were manufactured in compliance with API 6ACRA, 1st Edition.

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1 Scope

This report quantifies the hardness profile of both machined and rolled threads in precipitation hardened nickel-based alloys (PHNAs); studies the effects of both machined and rolled threads on hydrogen induced stress cracking (HISC) susceptibility in relevant PHNAs; tests these PHNA grades used for bolting per the requirements of API standards; and provides guidance for the use of the selected testing methodology and resultant test data in the petroleum and natural gas industry.

2 Normative References

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

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
damage tolerance index
DTI
A calculated parameter that uses fracture mechanics and mechanical properties to assess the critical defect size under a given stress intensity for a given material.

3.1.2
hydrogen susceptibility ratio
Hsr
A calculated parameter that uses applied stresses and mechanical properties to assess the magnitude of effect a specific thread or surface geometry has on the hydrogen embrittlement susceptibility of a given material.

3.1.3
KI_c
The critical stress intensity under Mode I loading conditions at which the onset of crack growth begins.

NOTE See ASTM E399 for additional information.

3.2 Abbreviations

For the purposes of this document, the following abbreviations apply.

CP	cathodic protection
CT	cut threads
CTOD	crack tip opening displacement
CVN	Charpy V-notched
DTI	damage tolerance Index
DTI_ρ	damage tolerance index of a given specimen with a threaded geometry (i.e. root radius) exposed to a given environment
EDM	electric discharge machining